



ASIA EDITION

Vol. 7 Issue 8

# Knowledge

SCIENCE • HISTORY • NATURE • FOR THE CURIOUS MIND

INCORPORATING  
SCIENCE WORLD

# FREE WILL THE GREATEST ILLUSION?

How science is  
discovering that you're  
not really in control p26



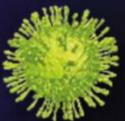
PPS 1745/01/2013 (022915)  
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Regent  
Media



PORTRAITS OF  
THE PLAGUE p75



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A BULLET p58

BBC

Knowledge

# Highlights

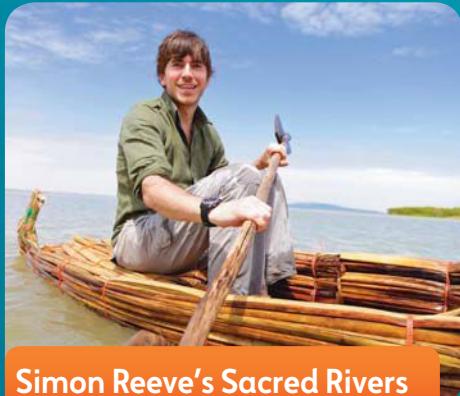
TV Channel



## Operation Cloud Lab: Secrets of the Skies

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### Extreme Fishing with Robson Green

Wednesdays at 8.55pm (JKT/BKK),  
9.55pm (SIN/HK/MAL/TWN)



### Life Below Zero Sr 2

Tuesdays at 9.50pm (JKT/BKK),  
10.50pm (SIN/HK/MAL/TWN)

Join Simon Reeve on an adventure as he explores three of the world's major rivers: the Nile, Yangtze and Ganges, uncovering their vast influence, and reveals how they unite, and divide, some of the most extraordinary parts of the world.

Robson Green is taking extreme fishing to a different level to outwit the weirdest, the most aggressive, and the hardest to catch fish ever.

Life Below Zero returns with an icy vengeance. In the weeks just before freeze up, four households embark on long treks in the blistering cold of Artic in their search for remote new hunting grounds.



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# On the cover

Vol. 7 Issue 8

SCIENCE



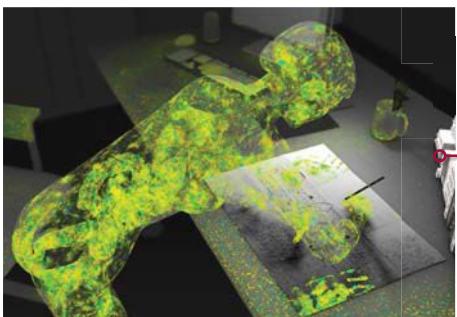
## **39 The Whole Truth And Nothing But The Truth**

## HISTORY



## 75 Portraits Of The Plague

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## 64 Microbes On The Move

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## 58 How To Make Anything Bulletproof

The cover of Knowledge magazine, issue 8, Asia Edition. The title 'Knowledge' is in large white letters, with 'SCIENCE • HISTORY • NATURE • FOR THE CURIOUS MIND' below it. A yellow circle on the left contains the BBC logo, and another on the right contains a woman's face. The central image is a man's profile with gears and a brain inside his head, and the text 'FREE WILL THE GREATEST ILLUSION?'. Other features include 'PORTRAITS OF THE PLAGUE', 'MICROBES ON THE MOVE', and 'HOW TO STOP A BULLET'.



## **26 Is There Really Such A Thing As Free Will?**

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Probably the greatest medical device concocted by Hollywood, but as with most things on the big screen, reality has to play catch-up. However, medical technology proves that cool is no longer the preserve of Dr 'Bones' McCoy

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Kevlar has revolutionised the way we protect soldiers as well as law enforcement teams, there is no doubt this polymer has saved many lives since 1971. Scientists are now looking at other alternatives beyond Kevlar

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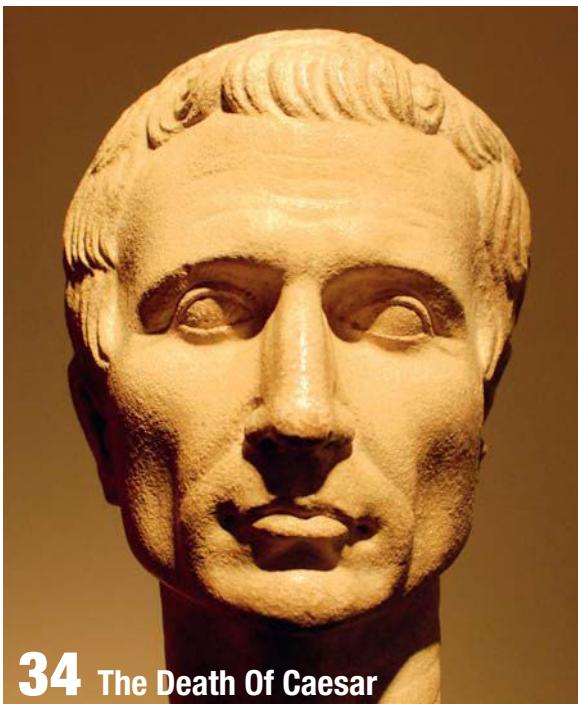


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### Free Will: The Greatest Illusion?



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Habitable planets may turn up in surprising places



## COMPREHENDING THE INCOMPREHENSIBLE

Free will, what is it really? Is it the stimulus that drives certain people to devote their lives to charity, academic pursuits, religious life or a life of thievery and crime? In more simplistic terms, does free will mean the options you choose to execute the first thing you wake up in the morning or whether to cycle, take the train or bus or drive to work?

Let's just say you have decided the night before to ride your bicycle to work, but when you wake up in the morning it happens to be raining and you change your mind. Is this all a pre-determined decision or just quite simply, your human need for self-preservation or some greater power at work?

Even as scientists delve deeper into the science of free will, they are no closer to confirming arguments for or against it. The reason for this can be summed up quite succinctly by theoretical physicist Dr. Michio Kaku, "The human brain has 100 billion neurons, each neuron connected to 10 thousand other neurons. Sitting on your shoulders is the most complicated object in the known universe."

**Ben Poon**  
ben@regentmedia.sg

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✉ We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine and/or on our website. We regret that we cannot always reply personally to letters.

## Experts in this issue...



### Simon Crompton

Simon, a former health editor for *The Times*, was always going to write for *BBC Focus* – it was inevitable. Or was it? Simon examines the war against free will on p26.



### Jo Carlowe

Jo writes for numerous titles, including the *The Guardian*, *BBC Good Food* and *Cosmopolitan*. She speaks to a former CIA agent about how to get someone to tell the truth on p39.



### Christine Evans-Pughe

Christine is a science and technology writer who has written for *The Independent*, *The Guardian* and *The Economist*. On p58, she looks at the future of bulletproof materials.



### Tom Ireland

Tom is the managing editor of *The Biologist*, the magazine of the Society of Biology. On p64, he looks at the personal colony of microbes that follows us everywhere we go.



## BBC Knowledge Magazine

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We welcome your letters, while reserving the right to edit them for length and clarity. By sending us your letter you permit us to publish it in the magazine and/or on our website. We regret that we cannot always reply personally to letters.



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# Snapshot



## Toxic beauty

In central Poland, coal ash leaks from the Belchatów power station through outlets into nearby clear waters, painting the surface with sinister grey veins. Belchatów is the largest coal-fuelled plant in Europe and emits more than 30 million tonnes of CO<sub>2</sub> every year, more than any other in the continent.

The shot was taken from a paraglider by Polish photographer Kacper Kowalski, as part of a project named 'toxic beauty' that features images of chemical plants, mines and landfill sites taken from a bird's-eye perspective.

"Coal-fired power generation comes with significant costs to the environment and human health," says

Chukwunonye Ezeah, a researcher in waste and environmental management at the University of Wolverhampton. "Water run-off from coal washeries carries heavy metals that contaminate groundwater, rivers and lakes, affecting aquatic flora and fauna.

"Most importantly for human health," he adds, "the combustion of coal releases emissions of harmful gases such as sulphur dioxide, nitrogen oxides and carbon monoxide, and various trace metals like mercury, into the air through stacks that can disperse this pollution over large areas."

**PHOTO:** KACPER KOWALSKI/  
PANOS PICTURES



## Making waves

Sliding down this 30m-tall wall of water as it cascades towards Praia do Norte beach in Nazare, Portugal, is the tiny figure of Garrett McNamara, a thrill-seeking surfer famous for riding monstrous waves.

The colossal swells begin when storms arising in the North Atlantic during winter push vast quantities of water towards the European coast. The unique features of the Praia do Norte coastline then transform this mass of water into the spectacular breakers pictured here.

"A deep water canyon offshore of Nazare allows the wave to travel towards the coast without losing too much energy along the way," explains Matthew Lewis from the School of Ocean Sciences at Bangor University.

"When a wave approaches the shoreline, the bottom of the wave starts to 'feel' the seabed, which slows its speed, resulting in energy loss. The headland also focuses the energy," says Lewis.

"The wave starts to slow down as it reaches shallower water, which changes its direction and focuses the mass of water and energy together, resulting in very large waves."

PHOTO: CORBIS

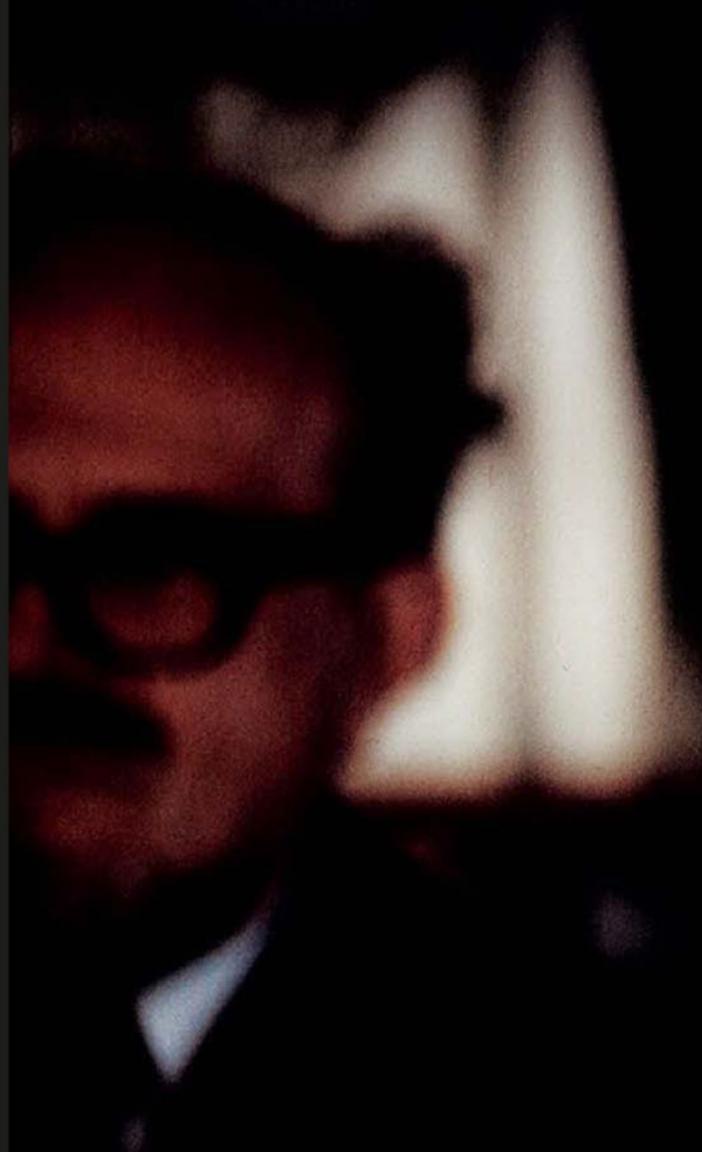


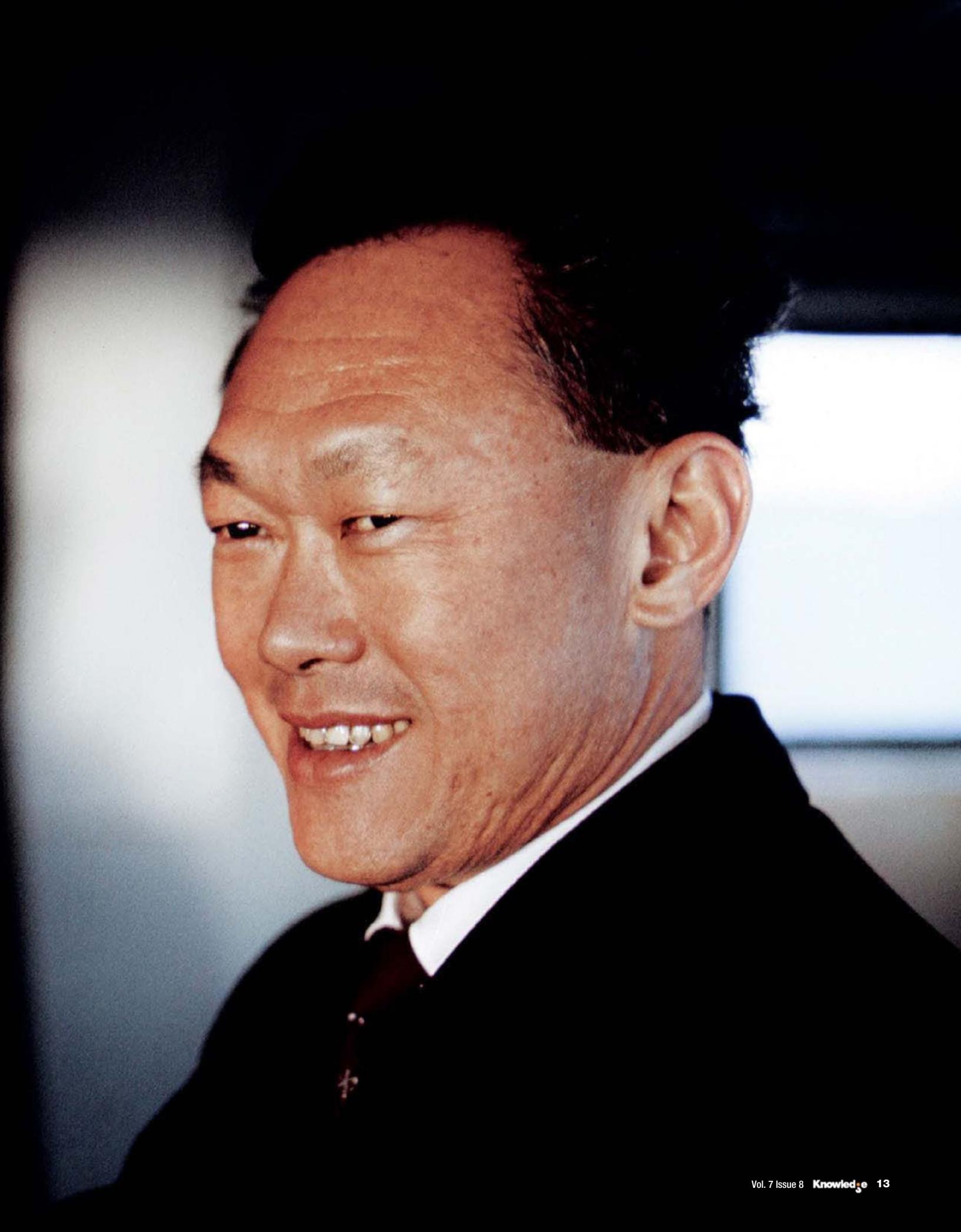
# Remembering Mr Lee Kuan Yew

On August 9th 2015, Singapore will celebrate her 50th anniversary of independence. A relatively short period when compared to other more developed nations around the World, but her progress was no less challenging for an island state with no natural resources, economy or infrastructure to begin with.

Singapore's progress from mudflats to a modern metropolis is due in no small part to Mr Lee Kuan Yew. For it was due to his leadership, vision, persistence, tenacity and incorruptibility that Singapore is able to punch above her weight on the World stage. As a testament to the respect that the people whom he fought and thought for all his life have for him, over 450,000 braved the elements to attend the lying in state at Parliament House and another 1.2 million went to 18 condolence centres set up across the island to pay their final respects and to give thanks to an outstanding individual who gave his entire life for Singapore, so that her citizens are proud to be known as Singaporeans.

**PHOTO:** AFP





# Update

THE LATEST INTELLIGENCE



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DAVID SHUKMAN

Why air pollution is a growing problem worldwide, and not just in China



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BAT FLIGHT EXPLAINED

How bats perform their in-flight acrobatics is a mystery no longer



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VOLCANIC PLANET

Why exoplanet 55 Cancri e has astronomers all in a lava

THE BIG STORY

## DARK MATTER MAY NOT BE SO 'DARK'

PHOTO: NASA/ESA/D HARVEY/EPPFDL/R MASSEY/HUBBLE

Galaxy clusters are helping researchers to study dark matter

**D**ark matter makes up a whopping 85 per cent of matter in the Universe, but no one knows exactly what it is. It is called 'dark' because it is thought to interact only with

gravity, making it invisible to telescopes. It can, however, be detected indirectly due to the distorting effect of its mass on the light from background galaxies, via a technique known as gravitational lensing.

Now, an international team of astronomers, led by researchers at Durham University, believes they might have observed the first signs of dark matter interacting with another kind of force. 



The Hubble Space Telescope allows astronomers to view collisions of distant galaxies

It is currently thought that all of the Universe's galaxies exist inside clumps of dark matter. Without the constraining effect of dark matter's extra gravity, galaxies such as the Milky Way would fling themselves apart as they spin.

The research team used the Hubble Space Telescope to view the simultaneous collision of four distant galaxies at the centre of a cluster of galaxies 1.3 billion light-years away. They noticed one such clump of dark matter appeared to be lagging behind the galaxy it surrounds by 5,000 light-years. To put this in context, it would take NASA's Voyager craft 90 million years to travel that distance.

Computer simulations run by the researchers show that this lag can be explained if dark matter interacts, even very slightly, with forces other than gravity. The extra friction caused by such interactions would make the dark matter slow down, and eventually begin trailing behind its parent galaxy. Exactly what force this could be, however, is unclear.

"We used to think that dark matter sat around, minding its own business," explains lead author Dr Richard Massey. "But if it slowed down during this collision, this could be the first dynamical evidence that dark matter notices the world around it. Dark matter may not be completely 'dark' after all."

There is more work to be done in determining exactly what is happening. Similar observations of more galaxies and further computer simulations of galaxy collisions are under way to confirm the interpretation and to investigate it further. And if the observations are confirmed, the work could lead to the emergence of new physics, the researchers say.

"Our observation suggests that dark matter might be able to interact with more forces than just gravity," says team member Prof Liliya Williams. "The parallel universe going on around us has just got interesting. The dark sector could contain rich physics and potentially complex behaviour."

## Timeline

### A history of dark matter

1933

1970

1981

2009

Swiss astronomer Fritz Zwicky proposes dark matter's existence after noting a discrepancy between the mass of visible matter and the calculated mass of the Coma galaxy cluster.

Cornell University's Vera Rubin notices that galaxies at the edge of the Universe move faster than expected. She suggests that dark matter could be causing this.

Physicist Mordehai Milgrom (right) disagrees. He says the measured mass is correct, but Newtonian mechanics needs updating. He dubs the theory Modified Newtonian Dynamics.



Construction on LUX experiment begins in South Dakota. It aims to detect weakly interacting massive particles (WIMPs), a hypothetical particle candidate for dark matter.

## GOOD MONTH/ BAD MONTH

### It's been good for:

#### FAST FOOD LOVERS

Usain Bolt confessed to eating 1,000 chicken nuggets throughout the Beijing Olympics. But he might be on to something. Small amounts of fast food can be just as effective as sports supplements in restoring muscle energy stores after a workout, according to a study at the University of Montana.

#### ARTSY TYPES

If you enjoy painting or sewing, you may be helping your memory. In a study carried out by the Mayo Clinic, those who engaged in arts in both middle and old age were 73 per cent less likely to develop mild cognitive impairment than those who did not.

### It's been bad for:

#### SHORT PEOPLE

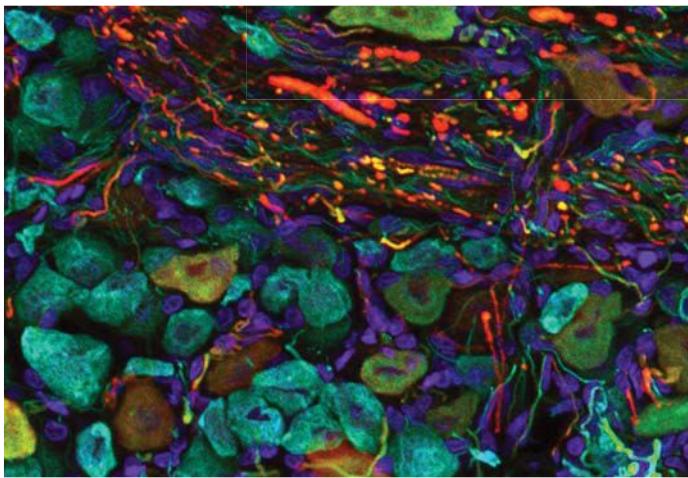
As well as being denied rollercoaster rides, it seems short people are also more at risk of heart disease. A team at the University of Leicester analysed genetic data from 200,000 people. They found that for every 6.35cm (2.5 inches) difference in height, the risk of coronary heart disease increases by 13.5 per cent. Compared to a 168cm (5ft 6in) person, a 152cm (5ft) person has a 32 per cent higher risk, on average. The exact reasons still remain unexplained.

#### NIGHT OWLS

Rise and Shine! Night owls are more likely to develop diabetes and degenerative muscle loss than early risers, even when they get the same amount of sleep, Korean researchers have found. The effect could be due to unhealthy behaviour or poorer sleep quality.

## Bats' extraordinary flying skills revealed

When it comes to airborne acrobatics there are few animals that can rival the agility of bats. However, quite how they achieve this has so far been a riddle.



Nerve cells on the brown bat's wings connect to more than one area on the animal's spine

Now, a team at Johns Hopkins University think they have the answer. Touch-sensitive cells clustered around tiny hairs that cover the bats' wings send information about airflow directly

to their brains, allowing them to make split-second adjustments in mid-flight.

"Until now, no one had investigated the sensors on the bat's wing, which allow it to serve as more than a propeller, a flipper, an airplane wing or any simple airfoil," said researcher Cynthia F Moss. "These findings can inform more broadly how organisms use touch to guide movement."

The team studied the big brown bat, a common species found throughout North America that's able to fly at speeds up to 32km/h. They found that the evolutionary process which allowed bats to form wings resulted in unusual tactile circuitry that not only enhances control during flight, but also allows bats to use their wings to climb, cradle their young and capture insects.

**The mystery of bats' in-flight acrobatics has been solved!**

They also found that the pattern of nerves in the bats' wings is different from that of other mammals. Neurones within the wings' skin connect not only to the area in the animals' spinal cords that is typically associated with forelimbs, but also to an area normally connected to the trunk.

The findings lay the groundwork for understanding how bats use sensory information to fly with incredible precision in the dark and catch prey in mid-air. Looking further forward, the new knowledge could even lead to engineers one day being able to design aircraft that can manoeuvre around obstacles by adjusting to air turbulence.

### NEUROSCIENCE

## Colour may 'set' your body's internal clock

As well as providing the perfect backdrop for a romantic meal or holiday snap, the stunning colours of sunset may be a signal for our bodies to reset our internal 'clocks'. It's been known for a long time that light plays a key role in governing the circadian rhythm - the 24-hour cycle that affects everything from sleep patterns to appetite. Now, a team at the University of Manchester has discovered that changes in the colour of light can 'set' the internal clocks of mice, a finding they think will also prove true in humans.

"This is the first time that we've been able to test the theory that colour affects the body clock in any mammal. It's always been very hard to separate the change in colour from the change in brightness, but using new experimental tools we

were successful," said lead researcher Tim Brown. "What's exciting about our research is that the same findings can be applied to humans. So in theory, colour could be used to manipulate our clock, which could be useful for shift workers or travellers wanting to minimise jet lag."

Besides the changes in light intensity that occur as the Sun rises and sets, twilight is bluer than regular daylight. The team created an artificial sky that mimicked the daily changes in colour and brightness and exposed the mice to their model. By recording activity in an area of the mice's brains called the suprachiasmatic nucleus, or SCN, the researchers found that many of the neurones were more sensitive to changes in colour between blue and yellow, than to changes in brightness alone.

**The colours of sunset may play a role in governing our internal 'body clocks'**

# Where's worst for pollution?

The airport tannoy announcement confirming a delay to our flight mentioned 'weather conditions' as the cause. We were in the western Chinese city of Ürümqi, and what looked like fog blanketed the runway. But it wasn't fog. It was something much denser and more toxic, a cloud of pollution, and it paralysed the airport for hours. Step outside and the smell was unmistakable: acrid but also slightly sweet.

China has attracted the most headlines for the appalling state of its air. In some cities, readings for key pollutants go far beyond World Health Organization limits and reach the highest point on the scale. But air quality is a problem that afflicts cities around the world: Delhi now has the unenviable title of being the world's worst. And while Britain's air is far cleaner than in the days of the 'pea soup' smogs that gripped London until the 1950s, there is still a problem. In one form of pollution, nitrogen dioxide, a dozen British cities have breached EU standards for years. Since I started reporting on pollution, I've become far more sensitive to it. Film beside a major road for more than a few minutes and you can't miss the odour. Wash your hands afterwards and the dirt in the basin can be shocking.

## DAVID SHUKMAN

The science that matters



Smog is an issue in big Chinese cities, from Ürümqi in the west to Qingdao in the east (pictured)

Most shocking of all was visiting a pollution monitoring station in central London and holding a pair of filters: one was new and white, the other had been sampling the air for 24 hours and was dark grey. That grey is in the air we breathe.

Researchers are getting better at working out where this stuff is coming from. Most UK pollution

is homegrown, but a lot also blows in from the Continent – a mix of gases and microparticles produced by everything from Parisian traffic to German farmers spraying their fields. The evidence about health effects is mounting up, too. Pollutants can enter the lungs and the bloodstream, and are linked to respiratory and cardiovascular conditions. In Britain, pollution

causes an estimated 29,000 extra deaths every year, and a forthcoming study may raise that estimate.

One piece of advice from pollution scientists: don't stand beside busy roads any longer than you have to.

**DAVID SHUKMAN** is the BBC's Science Editor. [@davidshukmanbbc](mailto:@davidshukmanbbc)

## WHO'S IN THE NEWS?

**Alex Zhavoronkov**

Director of the Biogerontology Research Foundation

### • Bio-what was that again?

Biogerontology. Essentially, it's the study of the biological aspects of ageing, otherwise known as 'senescence'.

### • Right. What's he said or done to get people talking?

Zhavoronkov has raised a few eyebrows by claiming publicly that he, as well as many others, will live to be 150 years old.

### • How so?

He argues that current advances in biochemical technologies can keep us healthy and youthful until future developments in regenerative medicine and gene therapy further extend our lifespans. He also says that, historically, many people have lived beyond 100, despite enduring tougher times than we are currently going through.

### • So what does he suggest we should do to live longer?

Zhavoronkov recommends that we should prioritise health and knowledge over material assets, monitor our cell counts and blood biochemistry, store tissue samples in a biobank for future access, and take 'geroprotector' drugs. He practises what he preaches, too, popping more than 100 pills a day.



## 10 DISCOVERIES THAT WILL SHAPE THE FUTURE

### 10 Solar storage material

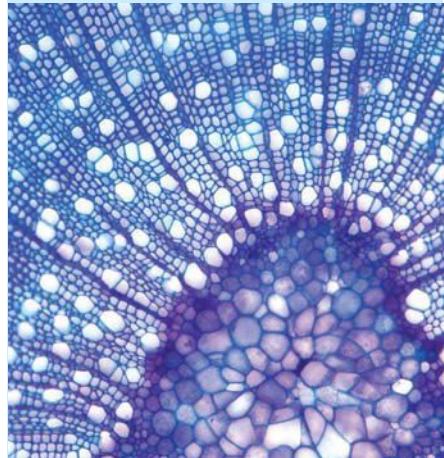


Imagine carrying sunshine in your pocket. Danish researchers are developing molecules known as Dihydroazulene-Vinylheptafulvene that store energy from the Sun by changing their shape, and release it

when they change back. The system isn't particularly efficient, but with further refinement it could prove to be an **environmentally friendly alternative to current lithium-ion batteries**, the researchers say.

### 9 Making trees grow faster

Mighty oaks from little acorns grow, the old saying goes. The only trouble is that it's a very slow process. Now, a team at the University of Manchester has identified two genes that are able to increase the growth rate of a poplar tree by speeding up cell division in the stem. **The work could increase supplies of renewable resources and help trees cope with the effects of climate change.**



A section of poplar tree with its cells modified

### 8 Self-powering camera



Cameras that run out of battery just as you're about to take a snap may soon be a thing of the past. A team at Columbia

University has created a pixel that can harvest the energy of the light that falls on it, as well as measuring it to create an image. Currently the camera can produce one image per second, indefinitely, in a well-lit room. **Eventually the technology could lead to cameras that can function with no need for external power**, the researchers say.

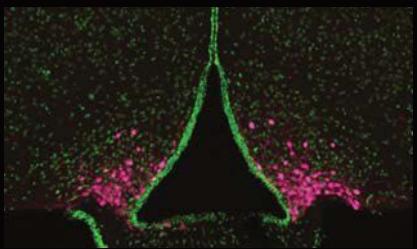
### 7 Centimetre-accurate GPS

If your sat-nav has ever led you into a muddy field, read on. Researchers at the University of Texas have built an inexpensive consumer GPS system that's 100 times more accurate than its current equivalent. The GRID system reduces location errors from the size of a large car to the size of a pound coin. **It could be used for delivery drones, self-driving cars, and even virtual reality gaming.** The system uses an inexpensive receiver to harvest accurate location information from antennas found in mobile phones.



### 6 An end to hunger pangs?

If you find that extra slice of cake too hard to resist, blame your AGRP neurones. Researchers at Howard Hughes Medical Institute found they generate negative feelings that cause us to seek food. With further study, the researchers say they may be able to **manipulate this process and put an end to hunger pangs.**



AGRP neurones in the brain manage feelings of hunger

## 5 The flexible robots are coming!

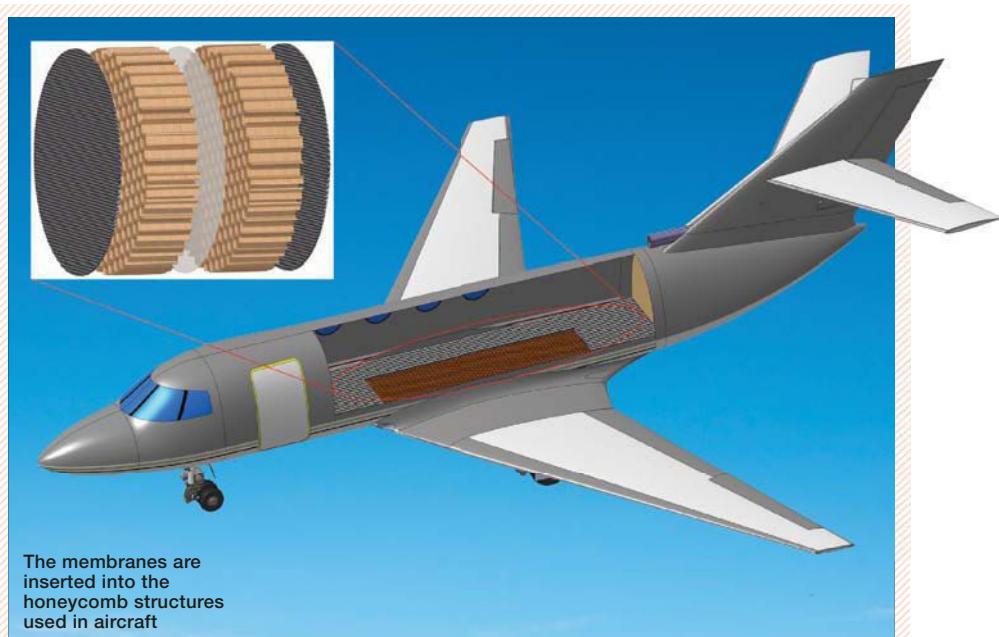
The days of stiff, immobile robots may soon be numbered. A team at the University of Pittsburgh has designed a synthetic polymer gel that mimics *Euglena mutabilis*, a single-celled, pond-dwelling organism. The gel can change shape and move using chemical energy. Scaled up, the gel could be used to create robots that are lighter and have an improved range of motion.

## 4 Artificial photosynthesis

Biodegradable plastics can now be made using artificial photosynthesis. The system, developed at the University of California, is made of tiny bacteria-coated wires that absorb solar energy and use it to convert CO<sub>2</sub> into acetate.



Those bacteria-coated nanowires up close



## 3 Quieter flights

As anyone who's ever tried to get 40 winks during a long haul flight knows, riding in aeroplanes can be a noisy experience. Help may be on the way, however, in the form of a thin rubber membrane that's been designed by a team at Massachusetts Institute of Technology.

The material can be placed into the cabin walls and could block 100 to 1,000 times more sound energy when installed. It works by causing soundwaves created by airflow on the outside of the aeroplane to bounce off, rather than pass through into the cabin.

## 2 Safer suction



Meet the Northern clingfish, a tiny fish with serious suction power. A team at the University of Washington is investigating the biomechanics of how its suction force can hold up to 150 times its own bodyweight even in wet, slimy environments. The key is an elastic

disc on their bellies that is covered in a microscopic hair-like structure. Similar technology could lead to a bio-inspired device that could stick to organs or tissues without harming the patient, or be used to tag whales and track them, the team says.

## 1 'Homing beacon' to beat bacteria

A molecular 'homing beacon' that attracts antibodies has been developed and used to 'tag' bacteria by a team at the University of California. One end of the molecule has a DNA aptamer that attaches to an invasive bacteria, while alpha-Gal, a sugar molecule, is at the other end. The alpha-Gal triggers the release of antibodies which then attack the bacteria. The technique may eventually be used to attack any type of bacteria or virus, or perhaps even cancer cells, researchers say.



Homing molecules at work

## 1 MINUTE EXPERT

### Methyl-adenine



**That sounds nasty.  
What is it?**

A sixth DNA base. Maybe.



**Hang on, I thought  
there were only four  
DNA bases?**

That's partly right. DNA is the main component of our genetic material and is made up four 'bases': adenine, cytosine, guanine and thymine, or A, C, G and T. These can combine in thousands of ways, giving rise to the incredible genetic variation we see in living beings.



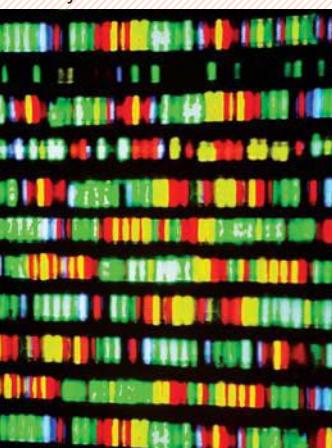
**So what's all this  
business about  
other bases?**

In the 1980s, a fifth base, methyl-cytosine or mC, was found to exist alongside the classic four. The 'methyl' bit means the cytosine molecule has an extra carbon atom and three hydrogen atoms. It is able to switch genes on or off and is involved in many diseases, including cancer.

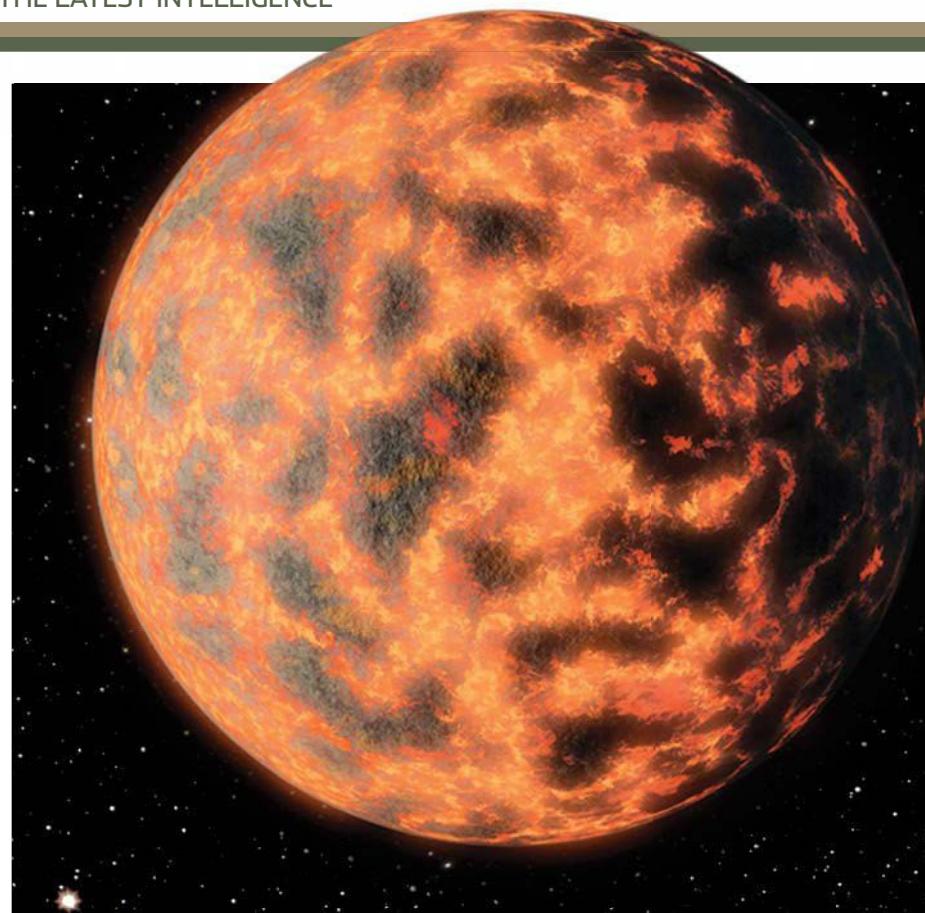


**...and the sixth?**

Now, researchers think methyl-adenine, mA, may also play a role in the expression of certain genes. However, further study is needed to determine exactly what it does.



The structure of DNA may be more complex than was previously thought



## SPACE

### Astronomers find volcanic planet

It's perhaps the closest thing to Mordor ever discovered: researchers at the University of Cambridge have observed a planet so teeming with volcanic activity that it can swathe itself in great clouds of ash and smoke.

Using NASA's Spitzer Space Telescope, the team recorded thermal emissions coming from the planet 55 Cancri e.

These emissions swung between 1,000°C and 2,700°C over a two-year period.

55 Cancri e is a rocky exoplanet about twice the size and eight times the mass of Earth. The so-called 'super Earth' is found 40 light-years away, in the constellation of Cancer, and orbits so close to its parent star that a year lasts just 18 hours. The planet is

tidally locked, so it doesn't rotate like the Earth does – instead there's a permanent 'day' side that receives all of the radiation from the star, and a 'night' side. Due to its relative proximity to Earth, 55 Cancri e is also among the best candidates for detailed observations of the surface and atmospheric conditions on rocky exoplanets.

"This is the first time we've

## THEY DID WHAT?!

**Neuroscientists make  
volunteers 'invisible'**

### What did they do?

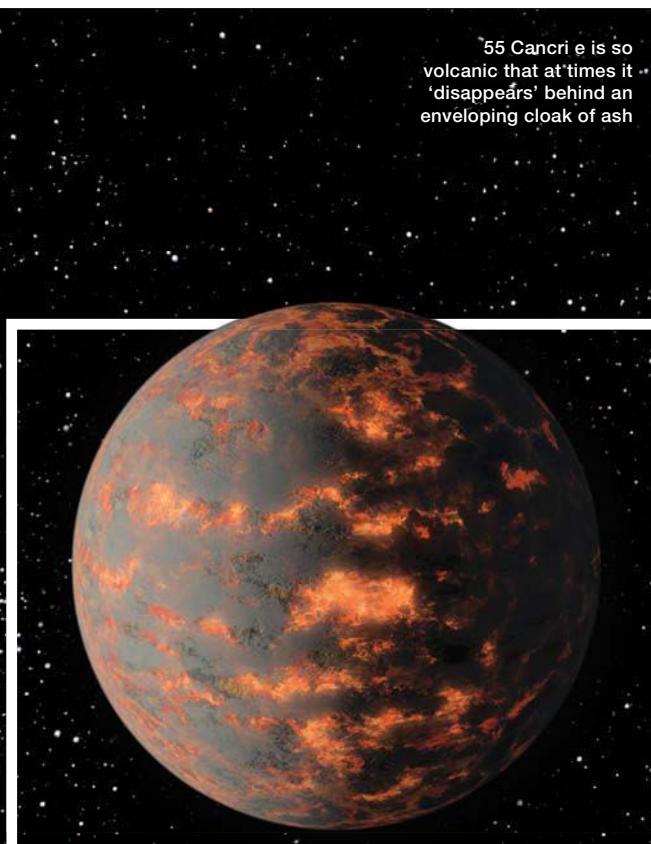
A team at the Karolinska Institutet in Sweden had volunteers wear head-mounted

virtual reality displays, set up so that when they looked down at their bodies they saw empty space. They then touched the participants' bodies with a large paintbrush, while imitating the movements with another brush in full view of the subjects. It took less than a minute for the subjects to transfer their sensation of touch to the

empty space where they saw the paintbrush move, making them feel as if their body was invisible.

### What did they find?

They also got subjects to perform in front of an audience both before and after they underwent the 'invisibility' session. The volunteers' heart rates were lower and they



seen such drastic changes in light emitted from an exoplanet, which is particularly remarkable for a super Earth," said researcher Nikku Madhusudhan. "No signature of thermal emissions or surface activity has ever been detected for any other super Earth."

Researchers believe this drastic change in thermal emissions could be due to intense volcanic activity on the surface spewing out huge volumes of gas and dust which sometimes

blanket the planet, making it look like a great ball of ash.

"When we first identified this planet, the measurements supported a carbon-rich model," said Madhusudhan. "But now we're finding that those measurements are changing over time. The most recent observations open up a new chapter in our ability to study the conditions on rocky exoplanets using both current and next-generation large telescopes."

reported feeling less stressed during the performance when they had undergone a short period of 'invisibility' beforehand.

#### Why did they do it?

The results of the study could be of value in developing new therapies for conditions such as social anxiety disorder, the researchers say.



The VR headset created a sensation of invisibility surprisingly quickly

## PATENTLY OBVIOUS with James Lloyd

Inventions and discoveries that will change the world

For those terrified of injections, relief may be on the way



### Pain-free pricks

Those who dread the doctor's needle may soon be in for a nice surprise. Students in the US have created a device that rapidly numbs the skin, reducing the pain of an injection. The three first-year students at Rice University have called their gizmo 'Comfortably Numb'.

It's a 3D-printed, single-use device consisting of two sealed chambers containing ammonium nitrate and water. When the device is twisted, the contents of the two chambers come into contact, triggering an endothermic (heat-absorbing) reaction. Placing the metal device against the patient's skin produces a numbing effect within 60 seconds, after which they can receive a shot painlessly. The invention will be useful for those who are about to receive an injection in a sensitive area.

**Patent application underway**

### No more spoilers

It's always the same – you spend ages carefully avoiding details about your favourite TV series, then someone goes and blurts out the killer plot twist on Facebook or Twitter. Well, Google feels your pain. The tech giant has patented a system that will keep track of the films and series that you're watching, flagging up a warning if someone posts something that could include a spoiler. Unfortunately, though, it won't stop your friends from giving the game away in the pub. For that, you'll need gaffer tape.

**Patent number: US 9,002,942**

### Smart wipers

Here's another step towards making cars fully automatic. Jaguar Land Rover has invented a system that automatically clears the rear windscreen whenever you look in the rear-view mirror. Sensors track your gaze and head movements, triggering an extra wipe of the windscreen when you check your mirror. It'll save you fiddling with the wiper settings, and the window will be free of rain and muck at just the right time. Next up: wipers that don't make that horrible squeak?

Patent application number: **US 20150066293**

## NEUROSCIENCE

### Observed: the precise moment the brain makes a decision



Sunny side up or over easy? Train or bus? Cappuccino or latte? Life is full of decisions. Now, researchers at Stanford University have successfully recorded the changes in brain signals that occur when a monkey makes a choice.

The team trained laboratory monkeys to perform a decision-making task that involved choosing between two targets on a computer screen. They then tracked the monkeys' brain signals as the decisions were made. Sometimes the monkeys were able to reach either target, giving them a free choice; at other times

one target was blocked, resulting in a forced choice.

By monitoring the monkeys' motor and premotor cortex using electrodes, the team were able to analyse brain activity during each individual decision. In a sense, they were able to read the monkey's mind during the free choices, when each decision may be different.

"We can now track single decisions with unprecedented precision," said Stanford neuroscientist Matthew Kaufman. "Brain activity for a typical free choice looked just like it did for a forced choice. But a few of the free choices were different. Occasionally, he was indecisive for a moment before he made any plan at all, and about one time in eight, he made a plan quickly but changed his mind a moment later."

The work could lead to more effective control algorithms for neural prostheses, which enable people with paralysis to drive a brain-controlled prosthetic limb or guide a neurally-activated cursor on a computer screen.



Matthew Kaufman, monkey mind-reader

## MICROBIOLOGY

### Microbe may be missing link in the evolution of complex life

It's one of the most fundamental questions in science: how did complex life evolve? Now, a team from Uppsala University in Sweden has moved one step closer to the answer after discovering a new group of microorganisms that represents a missing link in the evolution from simple to complex cells.

Dubbed *Lokiarchaeota*, or 'Loki' for short, the microbe was found in Loki's Castle, a 2,350m-deep hydrothermal vent located between Norway and Greenland.

All organisms on Earth are either prokaryotes, such as bacteria, which have simple cells, or eukaryotes, such as mammals, which have more complex cells. However, as the two cell types are so different in composition, biologists have long wondered how one evolved from the other.

"The puzzle of the origin of the eukaryotic cell is extremely complicated, as

many pieces are still missing. We hoped that Loki would reveal a few more pieces of the puzzle, but when we obtained the first results, we couldn't believe our eyes. The data looked spectacular," says researcher Thijs Ettema. "By studying its genome, we found that Loki represents an intermediate form between the simple cells of microbes and the complex cells of eukaryotes."

Despite having a very simple structure, the microbe was found to share many genes in common with eukaryotes. This suggests cellular complexity emerged in an early stage of evolution, the researchers say. However, further investigation is required to determine what functions the genes perform.

"We are just getting started. There is still a lot to discover, and I am convinced we will be forced to revise our biology textbooks in the near future," says Ettema.



Loki's Castle. Missing link microbe and Norse god of mischief not pictured

# Comment & Analysis

## How can milk foam hold up a spoon when it's only made of water and air?

The cappuccino looked all right to me, but then I'm not much of a coffee drinker. It had a pretty pattern in the foam on top, and it had apparently been made using fairly swanky coffee beans. But that wasn't good enough for the friend I was with. She picked up the accompanying metal teaspoon and placed it flat on top of the foam, with the handle of the spoon resting on the side of the cup. We watched in silence as the spoon sank slowly beneath the bubbles. "Rubbish," she sniffed. The waitress returned with my hot chocolate, which was more than half milk foam, and we repeated the test. The spoon sat there quite happily, and apparently this foam passed the test. Isn't that odd? Spoons fall through air and they fall through milk. So how is it that when you mix those two things together, they make something that behaves like a solid and can hold up a spoon?

I have a small milk-frothing device at home, and it's always hot chocolate o'clock, so the next day I roped my neighbour to assist and we did some experiments. We tried cold semi-skimmed milk first. Milk contains both protein and fats, and as the air was whisked in, the cup filled up with foam really quickly. The secret to a foam is a molecule with both a water-loving and a water-hating end. These coat the surface of each bubble, making a sort of cage around it. In the cold milk, the fats were playing that role, but there weren't very many of them. As we watched, the bubbles joined together to make bigger bubbles, and these eventually burst. The foam vanished almost as quickly as it arrived.

Then we tried heating the milk. Cold protein molecules are wound up into little balls, with their hydrophobic (water-hating) ends tucked safely away inside. But as the milk was warmed, the proteins unwound to reveal those ends. Suddenly, there were far more molecules that could act as a coating. The foam grew just as quickly, but this time it stayed put because there were lots of stable little cages for the bubbles. But it doesn't tell us why the mixture could hold up the raisins that we scattered over the surface.

In really smooth milk foam, the bubbles are too small to see – each one measures about one-tenth of a millimetre in diameter and the coating stops them from joining together. These foams are quite wet, and



**"I'm still not a coffee drinker, but I love the thought that you can build a solid structure out of a liquid and a gas"**

the bubbles are spherical squishy packages that pack together just like ping-pong balls in a bucket. Pushing on them just squashes the bubbles a bit, so they'll push back and can hold an object up. But if you push a bit harder, the bubbles squish enough to start sliding past each other. The more liquid there is between the bubbles, the less hard you have to push to get them to shuffle around. This was the issue with the failing

cappuccino. There was too little air and the bubbles could easily move out of the way of the spoon.

Like richer hot chocolate? Full-fat milk isn't so good for foam, because the fats and proteins stick to each other and not to the bubbles. But add a bit of cream, and fat takes over from protein to make even more decadent foams. So, to finish the experiments, we made some more milk foam using our most successful technique, and turned it into hot chocolate.

I'm still not a coffee drinker, so I'm not going to turn into a coffee snob. But I love the thought that you can build a solid structure out of a liquid and a gas. And even more, I love the idea that you can add this structure to chocolate and drink it. ■

**DR HELEN CZERSKI** is a physicist, oceanographer and BBC science presenter whose most recent series was *Super Senses*

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# FREE WILL THE GREATEST ILLUSION?

Neuroscientists peering into our brains are becoming ever more convinced that free will is an illusion; simply a creation of our mind that allows us a sense of control. Simon Crompton delves into the science to find out more...

ILLUSTRATOR: ANDY POTTS

**Y**ou were always going to start this article. It was theoretically predictable from the moment of the Big Bang. You were always going to read this sentence. And this one – each act the inevitable result of everything that preceded it. Every bumping together of atoms and molecules, the exact structure of your DNA, the precise combination of chemical and electrical signals that make you do what you do has been determined by the laws of science from the beginning of time.

That is what is known as ‘determinism’, and it cuts through traditional ideas of free will like a knife. In the past 30 years,

discoveries in neuroscience have freshly stoked the fires of debate about determinism versus human free will that have been crackling among scientists, philosophers and religious figures since at least the days of Socrates. And determinism, most famously advocated by Sir Isaac Newton, currently seems to be gaining the upper hand.

The reason for this is a sequence of brain experiments stretching back to the 1980s, which have indicated with increasing authority that our brains make decisions before we even become aware of them. Scientists today can wire you up to a computer and predict what choice you are

going to make many seconds before you believe you make it. If we’re not conscious of our decision-making, how can we be said to be acting voluntarily, to be ‘willing’ our every deed? And if we’re acting consciously, exactly what is determining what we do?

Scientific inquiry, it seems, is killing the very idea of free will. Or is it?

## Decisions, decisions

Imagine looking at a clock on a computer with a rapidly rotating hand, and being asked to push a button at any point decided by yourself. You have to





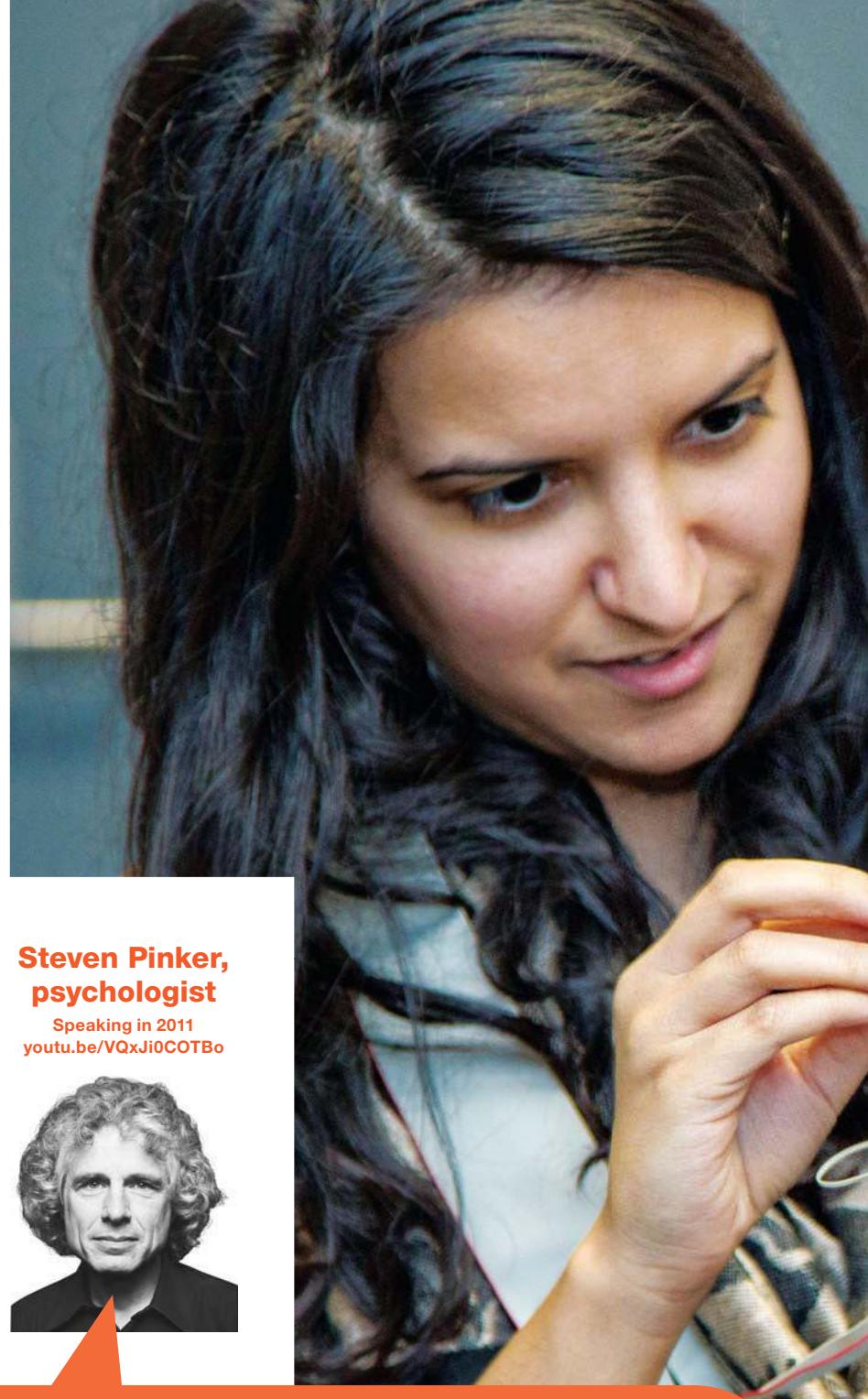
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→ note the position of the hand on the clockface at the moment you decide to move your finger. All the while, your brain's electrical activity is monitored using an electroencephalogram (EEG).

This was the experiment carried out by American neurologist Benjamin Libet in 1983 which caused a free will re-think. Libet calculated participants' precise conscious decision time, using the times they noted as their decision time and the time the button was actually pushed. Then he compared this decision time with a surge of brain activity that earlier research had shown indicated decision-making. He found that the brain activity started, on average, 300 milliseconds before subjects were conscious of making the decision. This change in brain activity that precedes conscious decisions, called readiness potential, has been deemed a blow to free will, suggesting that the brain prepares to do something well before we 'decide' to do it.

Libet's experiments were simple, but his findings have been elaborated on by his followers. In 2010, neurosurgeons and neuroscientists from UCLA and Harvard repeated Libet's experiment, this time inserting electrodes into the brain to record activity from individual neurones. They detected readiness potential up to 1.5 seconds before a decision.

What's more, brain-scanning research by Berlin neuroscientist John-Dylan Haynes in 2007 showed that some decisions we make can be predicted up to seven seconds in advance. He placed study participants into a brain scanner and asked them to push a button to their left or right side – whichever they wanted, whenever they wanted. The patterns of brain activity leading up to 'right' decisions were found to be different from 'left' decisions,

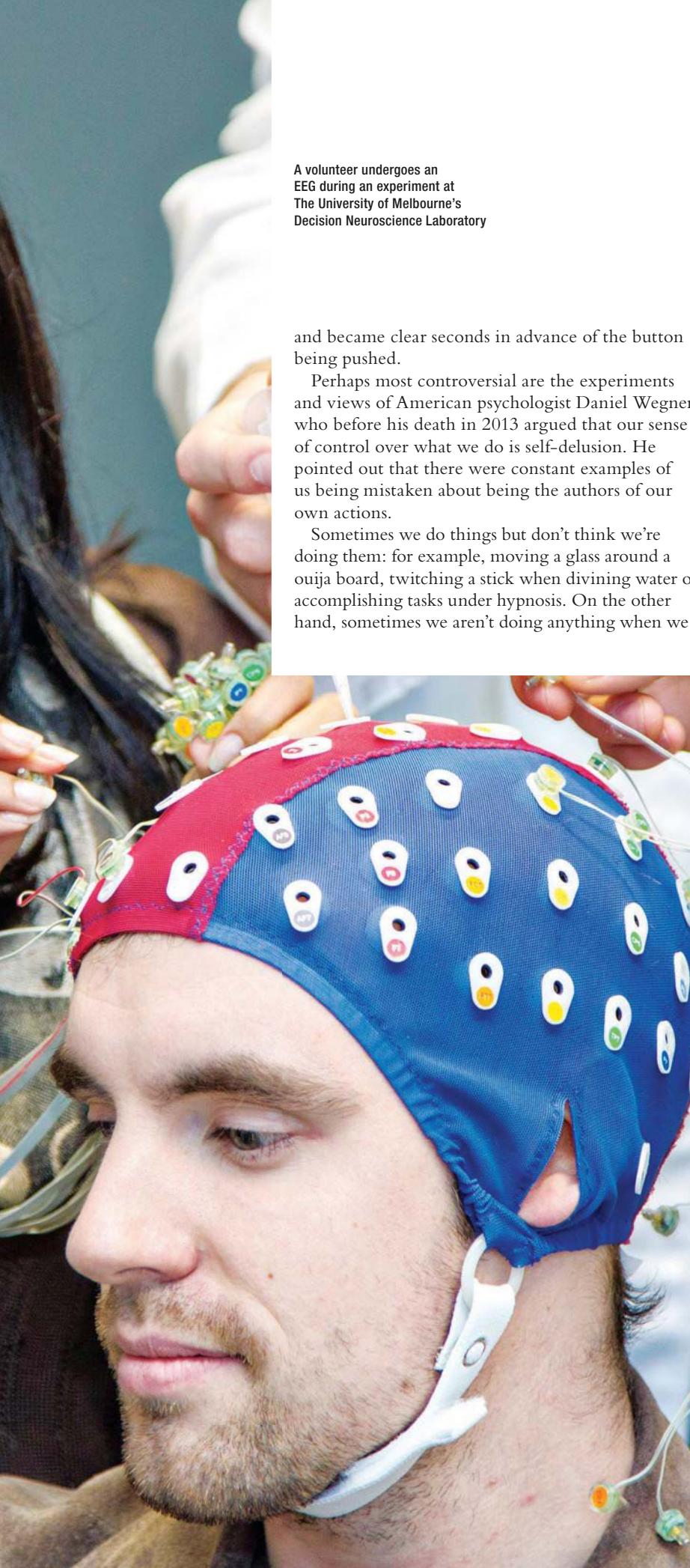


### Steven Pinker, psychologist

Speaking in 2011  
[youtu.be/VQxJi0COTBo](https://youtu.be/VQxJi0COTBo)



**I don't believe there's free will in the sense of a spirit or soul that reads the TV screen of the senses and pushes buttons and pulls levers of behaviour. Behaviour is the product of physical processes in the brain. But when you have a brain consisting of 100 billion neurones connected by 100 trillion synapses there's a vast amount of complexity, so human choices will not be predictable in any simple way from a given set of stimuli. We also know the brain is set up so that there are at least two kinds of behaviour: choosing how to move a chess piece is different from your iris closing if I shine a light in your eye. It's that kind of behaviour, that has a mental model of the world which can predict the consequences of certain behaviours, that carves out the realm of behaviour that we call free will.**



A volunteer undergoes an EEG during an experiment at The University of Melbourne's Decision Neuroscience Laboratory

and became clear seconds in advance of the button being pushed.

Perhaps most controversial are the experiments and views of American psychologist Daniel Wegner, who before his death in 2013 argued that our sense of control over what we do is self-delusion. He pointed out that there were constant examples of us being mistaken about being the authors of our own actions.

Sometimes we do things but don't think we're doing them: for example, moving a glass around a ouija board, twitching a stick when divining water or accomplishing tasks under hypnosis. On the other hand, sometimes we aren't doing anything when we

think we are. Wegner demonstrated this with a kind of reverse seance. He fixed a small board on top of a computer joystick, and asked two participants to sit on either side with their fingers on the board, causing a cursor to roam over pictures on a screen. They were told to stop the cursor whenever they liked. After the cursor stopped, the participants were asked how strongly they felt that they, individually, had chosen the stopping place. Invariably, participants believed they had controlled the landing place. The trick was that one of the two participants was, in fact, an experiment coordinator who had complete control of the cursor all the time. The movements of the true test subject didn't control the cursor at all.

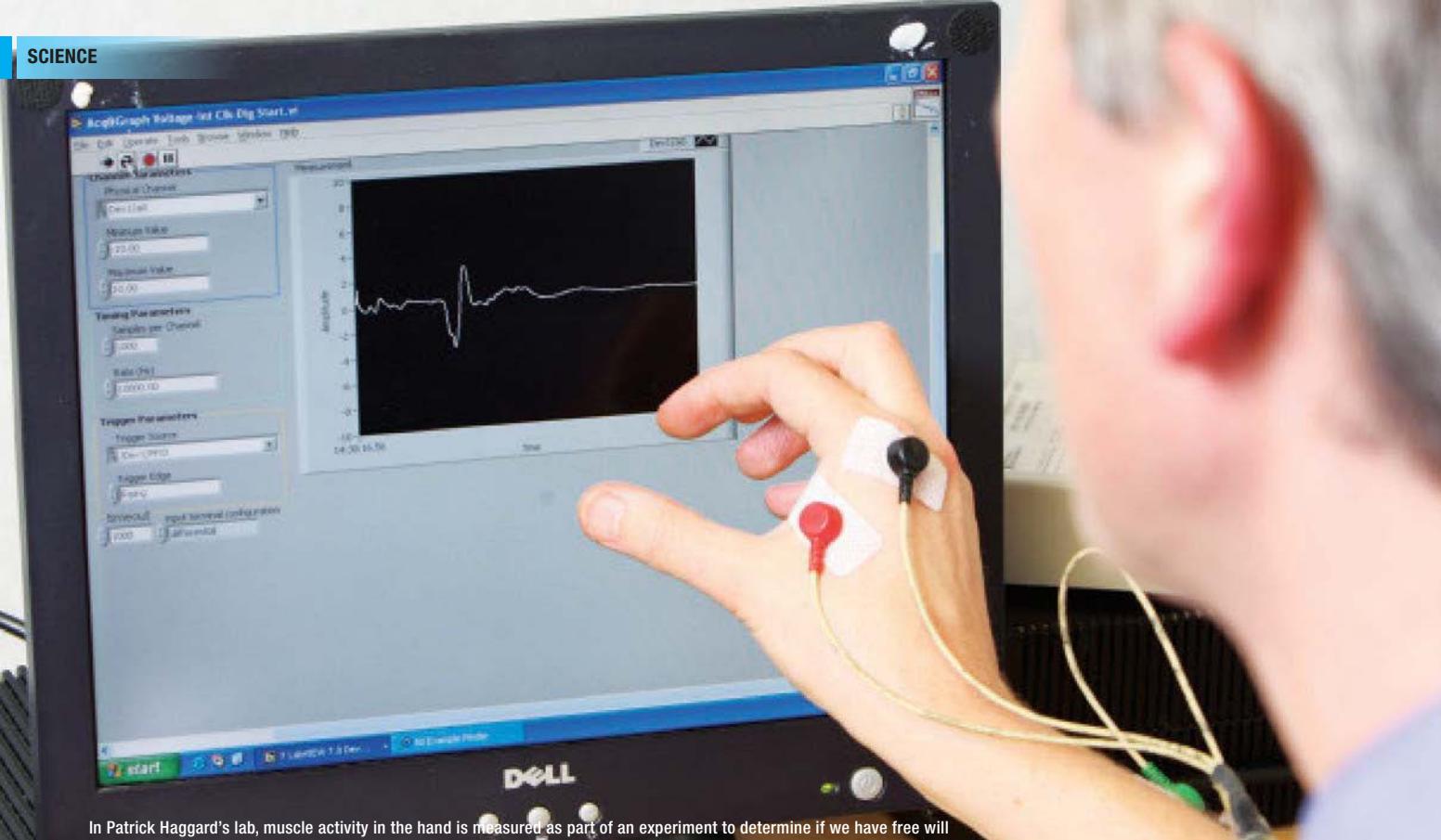


In Wegner's famous experiment, volunteers believed they were controlling the movement of a cursor on a screen – even though their input actually had no effect whatsoever on the cursor's movement

In other words, said Wegner, we fool ourselves constantly and have what he called “the illusion of conscious will”. This has led to other psychologists and neuroscientists taking the idea further – saying that the feeling of intention is something humans always attribute to their actions after the fact. We make up stories so that we can take ownership of actions that would have happened anyway.

Even for the most pragmatic of scientists, this sounds like a troubling vision of humans as programmed automata, our deeds the products of unconscious processes rather than thought. But that is by no means the whole story. If science has taken debates about free will beyond the traditional arenas of ‘independent’ action, the new understanding it has brought about human consciousness is revealing the inadequacies of talking about ‘free will’ in the first place. As a result, scientists and philosophers alike are





In Patrick Haggard's lab, muscle activity in the hand is measured as part of an experiment to determine if we have free will

“Free will is our capacity to see probable futures in time to take steps so that something else happens instead. What happens is determined, but it isn't as important as people have thought: it doesn't imply inevitability. We have to recognise that there are varieties of free will. The traditional varieties – who cares if we've got them? The varieties that matter, the varieties worth wanting, are perfectly compatible with determinism.

Do we have to give up something? Yes, we have to give up some of our ideas and ideology about freedom and blame and responsibility. That will scare some people, who want to be absolutist about responsibility. I mean, the idea of ‘in the eyes of God, that's a sin’... that has to go. What we replace it with is still a very rich and familiar concept, and that is: we are not deluded about our own capacity. We are determined to be masters of our fate, to a surprising and gratifying degree.”

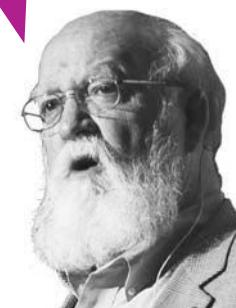
now engaged in framing new ways of looking at what it might actually mean to be ‘free’.

### The great debate

Patrick Haggard is a British neuroscientist who has collaborated with Libet and examines issues of free will and voluntary action as a professor at the Institute of Cognitive Neuroscience, University College London. Until recently characterised as ‘anti-free will’, he acknowledges his views have evolved as traditional debates seem increasingly irrelevant. One thing is clear, says Haggard: a scientific outlook can no longer accommodate dualist ideas – the belief held by religions and philosophers such as René Descartes that a soul or mind can exist separately from the brain and body.

“A neuroscientist has to believe that all our thoughts, feelings and experiences are the result of electrical and chemical events in the brain,” he says. That throws out of the window the idea that there is an ‘I’ telling the brain what to do.

But at the same time, he believes that ideas that we simply deceive ourselves into believing we have conscious will are going too far. He points to recent work by Aaron Schurger in France, which has brought into question whether the ‘readiness potential’ that Libet identified in the brain actually represents the brain planning what to do next. For some it has brought free will back into the neurological picture. Schurger developed earlier research indicating that when we make a decision based on, say, visual input, groups of brain cells start



**Daniel Dennett,**  
philosopher  
Speaking in 2014  
[youtu.be/joCOWaaTj4A](https://youtu.be/joCOWaaTj4A)



The 'dress illusion' (above and below) showed how neural noise leads to different conclusions about the dress's colour scheme



“Free will as a concept is so incoherent that it can't be mapped onto any conceivable reality. Many people agree that free will doesn't make any sense, and that it's some kind of illusion, but they think that nothing important changes, and in my view that is untrue. Most people imagine that a belief in free will is necessary for morality and it's necessary therefore for getting what we want out of life. I think that's clearly untrue.”

The popular conception of free will rests on two assumptions. The first is that each of us is free to think and act differently than we did in the past. The second assumption is that you are the conscious source of your thoughts and actions. Now, unfortunately, we know that both these assumptions are false. We live in a world of cause and effect. Everything that could possibly constitute your 'will' is either the product of a long chain of prior causes, and you're not responsible for them, or it's the product of randomness, and you're not responsible for that.



**Sam Harris,**  
**neuroscientist**  
**and author**  
Speaking in 2012  
[youtu.be/\\_FanhvXO9Pk](https://youtu.be/_FanhvXO9Pk)

assembling evidence in favour of various outcomes. When this neural noise rises to a peak, it crosses a threshold and tips into a conclusion. The famous dress optical illusion that took the internet by storm in March, for example, shows that different brains tip over into different conclusions on the basis of ambiguous evidence.

Schurger proposed that this constant neural noise is involved in all decision-making. He created a computer model of electrical activity as the brain assembled information, and found it looked similar to the patterns of Libet's readiness potential. He argued that what looked like a pre-conscious decision-making process might indicate a readiness to make a conscious decision, rather than the decision itself. In an experiment, he showed that participants who had built up the most neural noise were quickest in making 'spontaneous' choices.

## A WORLD WITHOUT FREE WILL

“What do you mean I don't have free will?” Many of us will tend to recoil at the very idea, because such a suggestion threatens many of the assumptions and institutions that our societies are founded on.

Religions that involve divine judgment make little sense if we don't

actually have conscious control over our thoughts and actions. And what about ideas of moral responsibility? If we know we don't have free will, does that lead to a world where we can behave as we want, because we cannot be held responsible for whatever we do?

Psychology researchers at Oregon

and Minnesota found that the more people doubted free will, the less they favoured punishments that make offenders suffer for their crimes – suggesting that a world that knew it had no free will might be more compassionate. They wanted rehabilitative punishments instead, focusing on

If it's true that there is really no such thing as free will, what are the implications for our day-to-day lives, and our society?

discouraging further crime. However the researchers, Azim Shariff and Kathleen Vohs, also found that people who are convinced that we do not have free will are more likely to cheat, lie and harm others during experiments.

According to Helen Beebe, Professor of Philosophy at

Manchester University, many philosophers believe that it is precisely because free will does not exist that we have to build social institutions and laws to stop us killing each other. “They see this as a pale imitation of moral responsibility,” she says. “However, I'd see it as real moral responsibility.”

Magicians and mind-readers have long known that free will is an illusion. In fact, we've been using that knowledge to our advantage for centuries. Any good performer can create the perfect illusion of free choice and yet secretly manipulate events so that the choice is anything other than free. It's fascinating to me that neuroscientists are only now discovering the science behind why this is possible. Choices only feel free because of a psychological principle called cognitive dissonance. Good performers use this to give an audience the feeling that they've made decisions for themselves, but in some tricks these choices are largely irrelevant as the performer has already decided on the outcome or knows what choices are likely to be made. An audience will swear they've exercised free will, and that's what makes this principle so perfect for us.



**Marc Paul,**  
psychological  
magician  
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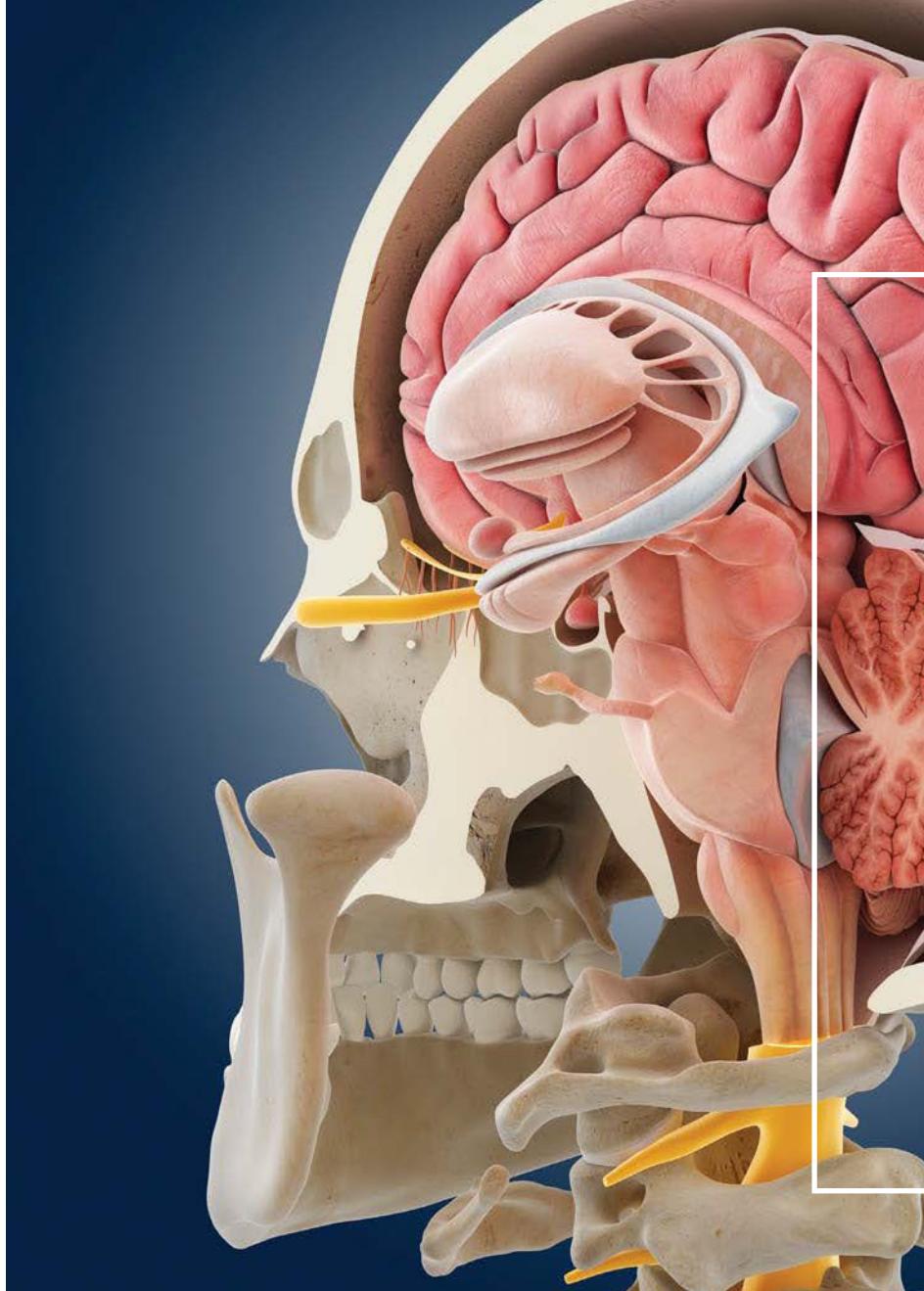
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“Schuriger is interesting,” says Haggard. “You could say that his theory is compatible with free will because this crossing of the threshold is the decision to act, but I think he’s rightly cautious about whether the process is conscious.”

Indeed, it is the big question of consciousness that needs to be addressed, because questions of free will are irrelevant without understanding it better. “I do think we have a conscious experience of what we are about to do,” Haggard continues, “but it’s for others to decide whether that is free will. It’s this stream of experience that our research is concentrating on. We need to know if there’s a difference between conscious actions – making a cup of tea, say – and those you can do unconsciously like walking. That will help us understand how consciousness affects our control of our actions.”

Neuroscientists are looking at two areas of the

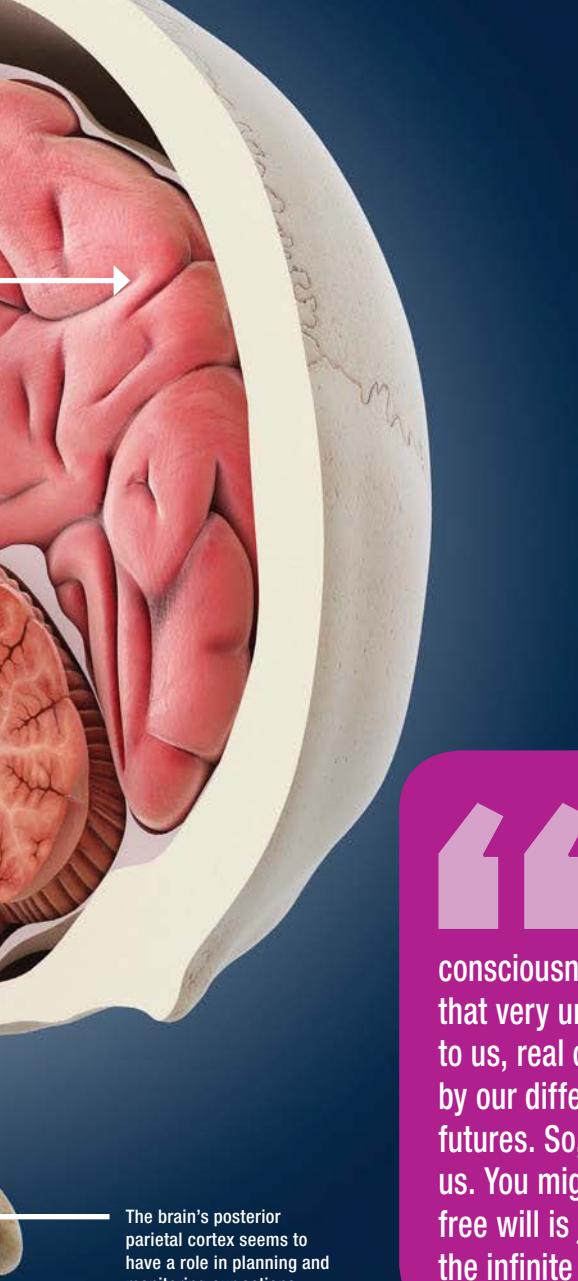


brain that seem to give us a sense of control over what we’re doing. The posterior parietal cortex at the back of the brain seems to have a role in planning and monitoring our actions. And the fronto-median cortex, where the two hemispheres meet, is active before movement. When doctors stimulate this area with electricity, patients have reported feeling the urge to move their arm. “That sounds a little bit like will,” says Haggard.

### The broader picture

Philosophers, too, are accommodating advancing neuroscience into their enduring debates about free will. The fact is, says Helen Beebee, Professor of Philosophy at Manchester University, that what neuroscientists are saying hasn’t come as a particular surprise to many.

“There’s a great philosophical tradition, one which I am part of, which says that even if



The brain's posterior parietal cortex seems to have a role in planning and monitoring our actions



Do we have free will? Yes, I believe we still do. It doesn't matter that we live in a deterministic universe in which the future is, in principle, fixed. That future is only knowable if we were able to view the whole of space and time from the outside. But for us and our consciousnesses, embedded within space-time, that future is never knowable. It is that very unpredictability that gives us an open future. The choices we make are, to us, real choices, and because of the butterfly effect, tiny changes brought about by our different decisions can lead to very different outcomes and different futures. So, thanks to chaos theory, our future is never knowable to us. You might prefer to say that the future is preordained and that our free will is just an illusion, but our actions still determine which of the infinite number of possible futures gets played out.



everything we do has a cause that can fully explain that it is going to happen, it's still perfectly possible to act freely. Before Libet, most of us thought there were prior causes anyway – we just didn't know what they were."

Beebee believes that a rounded look at human experience reveals that neuroscience is only part of the picture. "Say, for example, you looked at the last million years on a purely molecular level: you wouldn't see evolutionary processes, or animal behaviour. You'd have your story of how one thing led to another in terms of physics and chemistry, but you'd have missed out on some other very important stuff. If you look at the brain as a neurological machine, of course you're not going to find free will there, because it's not the level of description at which free will crops up."

"Why do we require determinism to be false to have control over our lives? None of us feel we have



**Jim Al-Khalili,**  
physicist

Writing in 2013  
[bit.ly/1aNFooC](http://bit.ly/1aNFooC)



Philosophy professor Helen Beebee says that it is possible to act freely and that we do not feel as if we are in a zombie-like state

a gun to our head, are being coerced into making our cup of tea or are in the grip of some hypnotic, zombie-like state."

The real lesson from recent research on human consciousness and decision-making is that neuroscientists and philosophers alike know that we are not robots, emptily fulfilling pre-ordained roles. We know that to accommodate the infinitely rich experience of being human, the brain has infinitely complex processes, and that current research is only scratching the surface of the simplest of these. Deciding whether to push a button is one thing; deciding whether to marry someone is another thing entirely. The case against free will is definitely not proven. ■

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**SIMON CROMPTON** is a science journalist, and a former health editor for both *The Times* and *The Daily Telegraph*



**Marked man**  
A bust of Gaius Julius Caesar. By March 44 BC, the great general had made some powerful enemies by increasingly acting like a monarch

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# New research The death of Caesar

For centuries we've been told that two Roman senators called Brutus and Cassius masterminded the plot to butcher Julius Caesar on the Ides of March. But is that the whole story? Did the brains behind the conspiracy reside somewhere else entirely – with one of Caesar's greatest allies?

By Barry Strauss

**W**hat do you say, Caesar? Will someone of your stature pay attention to the dreams of a woman and the omens of foolish men?" So said Decimus Junius Brutus Albinus to Gaius Julius Caesar. The 36-year-old Decimus spoke frankly to a man his elder by nearly 20 years, a man who was not only his chief but also Rome's Dictator for Life. Yet Caesar was fond of Decimus, a longtime comrade-in-arms and a trusted lieutenant, and so he let him speak. They met in Caesar's official residence in the heart of Rome.

It was the morning of 15 March 44 BC – the Ides, as the Romans called the approximate middle of each month: the Ides of March. The Senate was in session that day, its members eagerly awaiting the dictator's arrival. Yet Caesar had decided not to attend – allegedly because of bad health but, in fact, the real cause was a series of ill omens that had terrified his wife, Calpurnia.

Decimus changed Caesar's mind. Caesar decided to go to the Senate meeting after all, if only to announce a postponement in person. What he didn't know was that more than 60 conspirators were waiting for him there, their daggers ready. Decimus, however, was all too aware – he was one of the plots' ringleaders, and his actions that morning were about to change the course of history.

Despite this, most historians have traditionally cast Brutus and Cassius as the brains behind the conspiracy. In doing so, they've followed the lead of Plutarch, who wrote 150 years after the assassination, and Shakespeare, who drew most of his story from Plutarch. They tend to omit Decimus,

## IN CONTEXT

### Caesar

By 44 BC Gaius Julius Caesar was the most famous and controversial man in Rome. A populist political star and great writer, he excelled in the military realm as well, pulling off a lightning conquest of Gaul – roughly, France and Belgium – as well as invading Britain and Germany (58–50 BC). When his enemies, the old guard in the Senate, removed him from command, Caesar invaded Italy. He went on to total victory in a civil war (49–45 BC) that ranged across the Mediterranean. His challenge now was to reconcile his surviving enemies and to convince staunch republicans to accept his power as dictator. It was a daunting task.

Caesar's killers used the pugio dagger, like the one shown here, as it was easy to smuggle into the Senate House

who Shakespeare misnames 'Decius' and mentions only in the scene described above. Yet Decimus was key. His motives are less opaque than most think and his behaviour shows just how well organised the conspirators were.

The earliest surviving, detailed source for Caesar's assassination makes Decimus the leader of the conspiracy. Sometime within a few decades of the Ides of March, Nicolaus of Damascus, a scholar and bureaucrat, wrote a Life of Caesar Augustus – that is, of Augustus, Rome's first emperor (reigned 27 BC–AD 14). A later abridgment of this work survives and it focuses on the assassination.

Until recently, scholars have tended to dismiss Nicolaus because he worked for Augustus and so had a motive to attack the conspirators. But recent work suggests that Nicolaus was a brilliant student of human nature who deserves more attention.

A series of letters between Decimus and Cicero, all written after the assassination, also shed light on the plot, but they too have been neglected.

### Things turn sour

Unlike Brutus and Cassius, Decimus was Caesar's man. In the civil war between Caesar and the Roman general Pompey (49–45 BC), Brutus and Cassius both supported Pompey and then later changed sides. By contrast, Decimus backed Caesar from start to finish. During the conflict, Caesar appointed Decimus as his lieutenant to govern Gaul in his absence. At the war's end in 45 BC, Decimus left Gaul and returned to Italy with Caesar.





**In for the kill** A posse of senators stab Caesar to death in Vincenzo Camuccini's painting, completed in c1798. The plot succeeded, says Barry Strauss, because it was planned with military precision: after isolating their victim, the assassins acted rapidly and ruthlessly

Then things turned sour. Between September 45 BC and March 44 BC Decimus changed his mind about Caesar. We don't know why but it probably had more to do with power than principle. Decimus's letters to Cicero reveal a polite if terse man of action with a keen sense of honour, a nose for betrayal, and a thirst for vengeance.

Perhaps what moved Decimus was the sight of the two triumphal parades in Rome in autumn 45 BC that Caesar allowed his lieutenants in Spain to celebrate, against all custom. Caesar did not, however, grant a similar privilege to Decimus for his victory over a fierce Gallic tribe.

Or perhaps it was Caesar's appointment of his grandnephew Octavian (as Augustus was then known) as his second-in-command in a new war in 44 BC against Parthia (roughly, ancient Iran), Rome's rival in the eastern Mediterranean. Decimus meanwhile had to stay behind and govern Italian Gaul.

Whatever his motives, once he turned on Caesar, Decimus was indispensable. He was both the plotters' chief of security and their leading spy. As the only conspirator in Caesar's inner circle, Decimus was a mole, able to report on what Caesar was thinking. What's more, Decimus controlled a troupe of gladiators, which played a key role on the Ides.

Caesar remained in Rome between October 45 and March 44 BC – his longest stay there for years. He never revealed a programme but his actions betrayed that he

aimed to change Rome's government. He behaved in ever-more dictatorial ways, summed up in his adoption of the unprecedented title of Dictator for Life.

He maintained Rome's traditional republican magistracies but elections increasingly became mere formalities – Caesar had the real power of appointment. Consuls, praetors (magistrates) and senators saw power shifting to Caesar's secretaries and advisors – some of them had only recently become Roman citizens; some were even freedmen (former slaves). Caesar was not a king, but he had acquired the equivalent of royal power.

There was another issue at play here – the prospect of what would happen after Caesar's death. To his critics, the favour he

**“Decimus was the plotters' chief of security, and their leading spy. He was able to report on what Caesar was thinking”**

showed to Octavian raised the terrifying prospect of a dynasty.

Some Romans responded to Caesar's growing power with flattery. They voted him a long stream of honours including, most egregiously, naming him a god, with plans afoot for priests and a temple. Others, however, decided that he had to be stopped, and so they decided on assassination. True, they acted in the name of the Republic and liberty and against a budding monarchy but they also saw in his growing influence a threat to their own power and privilege.

Plans to assassinate Caesar are attested as early as the summer of 45 BC but the conspiracy that struck on the Ides of March did not gel until February 44 BC. At least 60 men joined it (of whom we can identify just 20 today – and some of them are little more than names). According to a later writer, Seneca, the majority of the conspirators were not Caesar's enemies – former allies of Pompey – but his friends and supporters.

That certainly can't be said for Brutus and Cassius, the best-known conspirators. Cassius was a military man and a former Pompey supporter who despised Caesar's dictatorial ways. As for Brutus, he was hardly the friend of Caesar whom Shakespeare depicts.

Brutus's mother was Caesar's former mistress. However, Brutus supported Pompey until the latter lost to Caesar on the battlefield in 48 BC, at which point Brutus switched sides. He promptly betrayed his ex-chief by

providing Caesar intelligence about the likely whereabouts of Pompey, who had escaped after the battle. Afterwards, Caesar rewarded Brutus with high office.

This, however, was to prove the high point of Caesar and Brutus's relationship. In the summer of 45 BC, Brutus divorced his wife and remarried. His new bride was Porcia, his cousin and, far more pertinently to this story, daughter of Caesar's late archenemy Cato.

Crucially, in the winter of 44 BC, Caesar's opponents began calling on Brutus to uphold the tradition of his ancestors, who included the founder of the Roman Republic, Lucius Junius Brutus, the man who had led the expulsion of Rome's kings hundreds of years earlier. And so, through a combination of pride, principle – and, perhaps, love for his wife – Brutus turned on Caesar.

### Military precision

The plot to assassinate Caesar succeeded because it was meticulously planned, and flawlessly executed. With generals such as Decimus, Cassius and Caesar's veteran commander Trebonius involved, one would expect nothing less than military precision. The assassins chose to end Caesar's life themselves rather than by hiring killers – a decision that showed their seriousness of purpose. And by striking at a Senate meeting they made it a public act rather than a private vendetta – an assassination and not a murder.

That this was a professional operation is even reflected in the killers' choice of weapon. Caesar's assassins attacked him with daggers and not, as is sometimes imagined, with swords. The latter were too big to sneak into the Senate House and too unwieldy for use in close quarters. In particular, the killers used a military dagger (the pugio), which was becoming standard issue for legionaries.

Military daggers were not only practical weapons but also honourable ones. Caesar's supporters later called the assassins common criminals and accused them of using sicae, a short, curved blade that had the negative connotation of a switchblade or flick knife. So, in 44 BC, Brutus issued a coin that celebrated the Ides of March with two military daggers. Again, he wanted to show that the assassins were no mere murderers.

The Roman Senate House still stands in the Roman Forum and most visitors assume that Caesar was killed there – but he was not, nor on the Capitoline Hill, as Shakespeare states. The assassination took place about half a mile away from the Forum in Pompey's Senate House, ironically built by Caesar's



This coin, issued by Brutus, one of the plot's ringleaders, displays the military daggers employed against Caesar

## “Before the end, Caesar wrapped his toga around his face and fell at the foot of the statue of his great rival, Pompey”

great rival. It was part of a huge complex including a theatre, a park, a covered portico, and shops and offices. Gladiatorial games took place in the theatre on the Ides of March, which gave Decimus an excuse for deploying his gladiators near Pompey's Senate House. Their real purpose was as a backup security force.

As a general, Caesar had a bodyguard but he made a point of dismissing it after returning to civilian life in Rome. He wanted to seem accessible and fearless. What's more, only senators could enter a Senate meeting, so most of Caesar's retinue would have had to remain outside the building. This made the dictator uniquely vulnerable inside the Senate House. Still, Caesar had appointed many of the senators personally, and they included military men. If they came to Caesar's aid, they could overwhelm the assassins.

The assassins' response to this threat was to attack at speed, isolating their target before striking. Even before Caesar took his seat on the tribunal, several assassins stood behind

the chair while others surrounded him as if trying to grab his attention. The truth is that they were forming a perimeter.

Then the attack sprang into action. Tillius Cimber, a hard-drinking scrapper of a soldier whom Caesar favoured, held his hands out disrespectfully and pulled at Caesar's toga. At this signal, his co-conspirators struck, led by Publius Servilius Casca.

Caesar immediately called out to Cimber, “Why, this is violence”, and hurled an oath at Casca, labelling him either “impious” or “accursed”. However, he never said: “Et tu, Brute?” (“You too, Brutus?”) – that phrase is a Renaissance invention. Ancient authors report a rumour that Caesar said to Brutus, in Greek: “You too, child.” But they doubt that he even said that.

Caesar, the old warrior, tried to fight back. He stabbed Casca with his stylus – a small, pointed, iron writing utensil – and managed to get back up. Two of his supporters among the senators, Lucius Marcus Censorinus and Gaius Calvisius Sabinus, then attempted to reach him but the conspirators blocked their way, and forced them to flee.

Meanwhile, Trebonius had been assigned to buttonhole his old comrade Mark Antony and engage him in conversation outside the Senate's door. Antony was a veteran soldier, strong, dangerous and loyal to Caesar. If he'd entered the Senate room, he would have sat on the tribunal with Caesar and could have come to his aid.

With Mark Antony detained by Trebonius, there was little Caesar could do to defend himself. It probably took only minutes for him to die – succumbing to what most of the sources state were 23 wounds. Before the end, he wrapped his toga around his face and, in an ironic turn of events, fell at the foot of a statue of his rival, Pompey.

For all its brilliance, the plot to kill Caesar didn't prove the panacea that the assassins hoped. Civil war soon broke out again and, to a man, they were to suffer violent deaths. What's more, the Republic that they aimed to defend perished and gave way to an empire. That, however, does not brand them as foolish idealists. It merely shows that their political acumen did not match the military skill they displayed on the Ides of March. ■

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**BARRY STRAUSS (@BARRYSTRAUSS)** is a professor of history and classics at Cornell University. His latest book, *The Death of Caesar: The Story of History's Most Famous Assassination*, is published by Simon & Schuster.

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# TRUTH WILL OUT

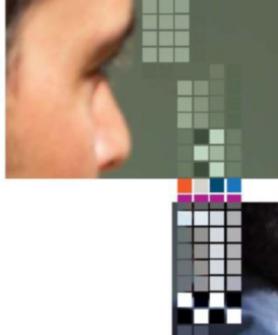
**In a new book, a former CIA officer reveals how to get anyone to tell you the truth. Jo Carlowe uncovers the tricks of the trade...**

**S**ocial psychologist Jerald Jellison famously claimed that humans are lied to 200 times a day. Little wonder, then, that reams have been written on how to spot a liar. But what do you do if you think someone has told you a fib? How do you convince them to tell you the truth when it may be in their best interest to lie? Well, former CIA officer Philip Houston, co-author of *Get The Truth*, believes he knows how.

In his 25-year career with the CIA, working as both an investigator and a polygraph examiner, he has eked confessions from some of the most entrenched liars, including terrorists and spies. And he says the techniques he uses in real-life counterterrorism and criminal investigations are applicable to all of us in our daily lives. There are methods that we can use in real-life situations to get a partner to admit to an infidelity, or a child to confess to a misdemeanour.

Surprisingly, the way to the truth has its roots not in relationship psychology, but in the science of persuasion. We obtain the truth by getting people to use short-term thinking. A shopping channel presenter, for example, will never say, "pick up your chequebook" because that will get viewers thinking about their finances





→ (or lack of them). Instead, they will say, “pick up the phone”. Likewise, agents in pursuit of the truth will do everything in their power to stop you thinking about the long-term consequences of your actions. And both salespeople and investigators use a ‘sales pitch’ to get you to switch focus away from your own goals and onto theirs.

### Sell the truth

In the case of the criminal investigator, the ‘sales pitch’ is actually the interrogation. This differs from the initial interview, which is a dialogue in which the investigator asks questions and the suspect responds. By contrast, the interrogation is a monologue in which the investigator does most of the talking. It is akin to the marketer’s sales pitch, but instead of a product, the investigator is selling the idea that telling the truth is the only way forward.

“The interview is often not effective because each question is another opportunity to lie. With every lie the person tells, they become more psychologically entrenched [committed] in maintaining the lie,” Houston explains.

To overcome this, the interrogator can switch to a monologue to lead the person into short-term thinking, causing them to become temporarily more focused on the rationale provided in the monologue than the long-term consequences.

“If a person is truly thinking clearly and logically, they should never confess – confession is a losing proposition for them,” admits Houston. “When we are training law enforcement officers, we often joke that in the interrogation, they have to become an 8ft x 10ft [2.4m x 3m] condominium salesman. That is extremely difficult real estate to sell, but the concept of short-term thinking is so psychologically powerful that it makes their monologue effective and successful.”

The methods are universal and can be used to elicit the truth from anyone – not just hardened criminals. And it turns out that the truth is not so hard to reach, because humans actually like to unburden themselves. Indeed, a Canadian

**“The more you question someone who is lying, the more psychologically committed to their lie they become”**

**Philip Houston, former CIA officer and co-author of *Get The Truth***



Know someone is lying? You might not need to dust off the old polygraph machine to get a confession



## WHAT MAKES SOMEONE MORE LIKELY TO LIE?

### THEIR SOCIAL CLASS

US scientists have found that the upper classes lie more in negotiations and cheat to win money more than the lower classes. When asked about values, the upper class participants had more favourable attitudes towards greed, which may go some way to explain the correlation between social nobility and ethical ignobility.

### THEY ARE PRESSURED FOR TIME

Psychologists asked participants to roll a dice and to report the result to determine their pay. Those given a short amount of time to report the outcome were more likely to lie. Experts suggest that when given more time, individuals are unable to inwardly justify lying and so they tell the truth.

### THEY WERE RAISED BY LIARS

Children lied to by adults are also more likely to lie. In one study, children were told there were sweets in another room. When the kids discovered there weren't any sweets, they were more likely to cheat and lie in a subsequent task than children who were not lied to at the outset.

### IT'S THE AFTERNOON

We are more likely to lie in the afternoon than the morning. Studies show that we are 20 to 50 per cent more likely to be dishonest in the afternoon, by lying and cheating more in various tasks. Experts put this down to 'psychological depletion' – as the day wears on we become cognitively weaker.

### THEY WANT PEOPLE TO LIKE THEM

Studies show that 60 per cent of people lie at least once during a short conversation with someone new and on average tell two to three lies. Women are more likely to lie to make the other person feel good, while men are more likely to lie to make themselves look better.

neuroimaging study from 2014 revealed that our cortical reward system is more active when telling the truth than when lying. In other words, we get more satisfaction from being honest.

"We tap the very same principle in every interrogation scenario we encounter, whether the aim is to get a terrorist to disclose the details of a bomb plot, a serial killer to confess to a murder or a child to admit they didn't do their homework," says Houston. The key to success is to transfer to the monologue the moment you are confident that you are not being told what you need to know.

"Remember, the more you question someone who is lying, the more psychologically committed to their lie they become," warns Houston.

#### Good cop

So how do you switch from a friendly dialogue into the more serious monologue? Houston recommends you make what's known as a 'transition statement' that is a Direct Observation of Concern (DOC), an

example being: "Something is clearly on your mind."

"The DOC is critical. It sends the simple message in a non-adversarial tone that everything the person has done to try to get away with the act of wrongdoing has failed. It psychologically orientates the person's thinking to the realisation that they need a new game plan, and the interrogator is perfectly positioned to provide that game plan via their monologue." In essence it says: 'You have failed so don't think your way any more – think my way'.

In the 'interrogation phase' it is more effective to use statements rather than questions. "If you ask a question, it signals that you still don't know if they're guilty, so they still have a chance to convince you they're not," says Houston.

Statements suggest that the truth is a given. As more facts come into play, you can make your proclamations stronger. 'I know the who, I know the what, now I need to understand the why', is an especially useful statement.

"This particular approach is very effective because it causes the person



During his 25-year CIA career, Philip Houston extracted confessions from seasoned spies and terrorists





→ to ask themselves 'why is the why so important?' The answer is often a realisation that the 'why' could influence the severity of the consequences," says Houston. "As a result, the person often initially fabricates or fudges on the 'why'. That's okay, because virtually any explanation of 'why' equals an admission of guilt. Once we have the confession, we can coax the real motivation out of them."

### Guilt trip

In a professional interrogation, the investigator may introduce a Direct Observation of Guilt (DOG) such as: "We can't eliminate you from our suspects."

Want the truth?  
Don't shout and yell  
at people – it will only  
make them jump on  
the defensive

**"Lessening of fear by relying on the monologue and short-term thinking is more powerful and effective than instilling or increasing the fear"**

**Philip Houston, former CIA officer and co-author of *Get The Truth***



However, Houston only recommends the layperson uses the DOG if they have irrefutable evidence on which to base it.

When giving their monologue, CIA interrogators will minimise, rationalise and generalise the act of wrongdoing in order to

bring the person closer to a confession. Statements like: 'We've all been there' or 'It's not the end of the world' are not unusual. A study from the University of Montreal's School of Criminology found that methods such as minimisation are

effective at getting suspects to open up. Houston believes these techniques are permissible but must be tailored to suit the seriousness of the situation and likely outcome.

"I would encourage parents to avoid using minimisation to the degree that they leave their child feeling they have been hoodwinked. They also don't want to leave their child with the impression that this is how normal life is handled. This approach is reserved when there is significant deception and the truth is critical to resolution," he says.

Unlike Houston, few of us will be faced with situations in which getting to the truth is critical to national security, but there will be plenty of other times when these methods can come in handy. Some useful transition statements to elicit the truth in



## 5 STEPS TO GET ANYONE TO TELL YOU THE TRUTH

1

### KEEP THEM IN SHORT-TERM THINKING

You need the person not to dwell on the consequences of their actions, otherwise they'll worry about job loss, divorce etc. To achieve this, minimise the seriousness of the situation with statements such as: 'It's not the end of the world' or 'It's a fixable problem'.

2

### SOCIALISE THE SITUATION

Make the person feel that there are others in the same boat, so they don't feel isolated. This can be done with a monologue that includes statements such as: 'It's nothing I haven't dealt with before' or 'In our world, this is the sort of thing that happens all the time'.

3

### FOCUS THEM ON TELLING THE TRUTH RATHER THAN ON THE ACTION ITSELF

The person needs to be convinced that the only way out of their current predicament is to be completely truthful to you. Here is an example of a useful statement: 'This is a fixable problem. To fix it, we need to get everything onto the table. That's the only way'.

4

### MAKE A DIRECT OBSERVATION OF CONCERN

Ask questions such as: 'Something is clearly on your mind' or 'Help me understand what I am missing'. With more facts, make the transition to a direct observation of guilt: 'I know the what and the who, but I need to know the why'. Or stronger still: 'Based on the facts, it is clear you did it'.

5

### SLOW YOUR SPEECH, TALK SOFTLY AND BE POLITE

If you rant, the person will focus on your behaviour rather than their own and become resistant. Choose your words carefully. For example, 'you took' rather than 'you stole', otherwise you'll conjure fears of job loss or prison and the person will quickly become defensive.

your personal life include the following:

1. You suspect your partner of cheating on you. 'Everyone makes mistakes, we're all human, we all make mistakes. What determines the future is not the mistake but how one handles it.'

2. You suspect your child of hiding something from you. 'Before you say anything, you need to understand that I need the whole story here. Anything less isn't going to work.'

3. You feel a colleague has been deceptive. 'I understand how things happen, however, it would be really helpful for me to have real and candid feedback regarding this situation.'

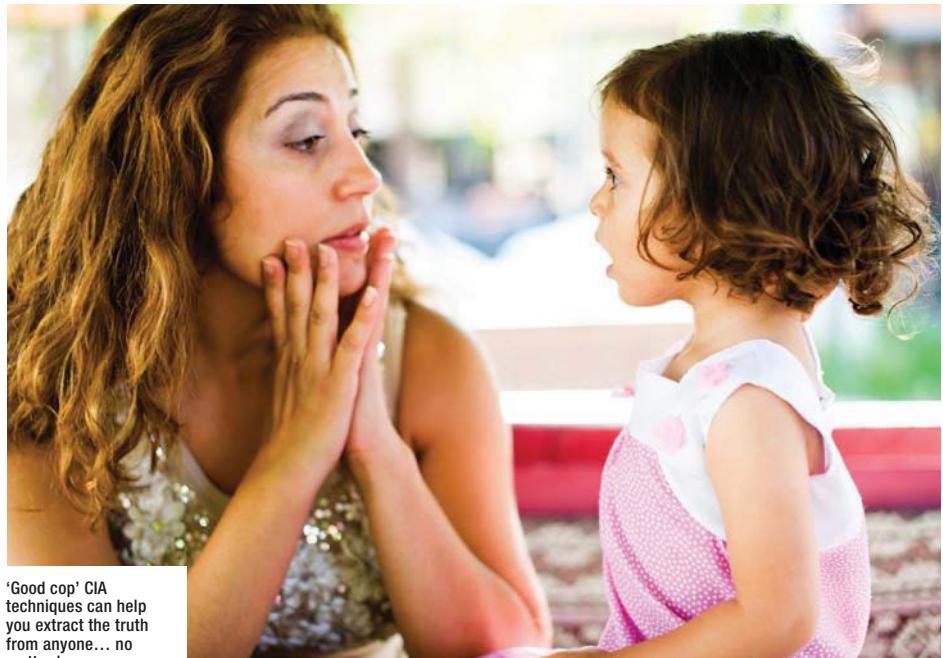
In all cases, the statement has to be delivered in a respectful and low-key manner. Houston says that we should 'SEL' ourselves if taking this approach. That means Slow your rate of speech, Engage by orientating your body and your focus on the person (but not in a challenging way) and Lower your voice by speaking softly.

In short, what you are doing is compelling the other person to move from wanting to deceive you to feeling compelled to tell you the truth. And it is all done without threats or violence.

In recent years, the CIA has been accused of using much more brutal methods in its interrogations, particularly with al-Qaeda suspects following the September 11 attacks.

### Torture truths

Torture is prohibited under the Geneva Conventions and in international human rights laws. But perhaps the greatest argument



'Good cop' CIA techniques can help you extract the truth from anyone... no matter how young

against torture is its ineffectiveness. In December of last year, The Senate Intelligence Committee concluded that the CIA's 'enhanced interrogation techniques' produced either no intelligence or 'fabricated information' that resulted in faulty intelligence.

"The lessening of fear by relying on the monologue and short-term thinking is more powerful and effective than instilling or increasing the fear," agrees Houston.

Indeed, the notion that good cop is better than bad cop is supported by science. A study by Michel St-Yves and Nadine Deslauriers-Varin from the University of

Montreal's School of Criminology found suspects were more likely to confess if they had a good rapport with their interrogator. According to the researchers, getting criminals to admit their guilt is 'an art form' that relies on finesse rather than coercion.

Getting physical might elicit a confession of sorts, but it won't bring you the truth. Convincing a person through charm and guile will. ■

**JO CARLOWE** is a science journalist who writes for *The Times* and *The BMJ*

# CAN WE MAKE A REAL TRICORDER?

**A Star Trek-style scanner would eliminate routine trips to the GP, allowing any of us to claim: "Dammit, Jim, I'm a doctor!"**

**Lilian Anekwe reveals the future of healthcare**

**T**he crew of the USS Enterprise became ill with alarming regularity. From Andorian shingles to Zanthy fever, all manner of intergalactic diseases were waiting to pounce on the crew whenever they set foot on alien planets. Mercifully, the ship's doctor always had a tricorder to hand, which could diagnose all manner of alien ailments in seconds. A quick once over was all it took to find out if a patient had a case of choriocytosis (a deadly disease for Vulcans) or just a common cold. There were no lab tests, no needles and no waiting. It's an idea that seemed more science fantasy than fiction, but that might be about to change.

Last year, a new US\$10m X Prize was launched that challenged inventors to build a real-life tricorder. The X Prize's philanthropic backers are offering to fund a team that can design a device weighing less than 2.3kg that is "capable of capturing key health metrics..." 

ILLUSTRATION: ANDY POTTS



Scan this QR Code for  
the audio reader

to accurately diagnose 16 health conditions [and] five real-time health vital signs: blood pressure, heart rate, oxygen saturation, respiratory rate and temperature." Okay, so it might not be smart enough to take to an alien planet any time soon, but could it launch a revolution in personal medicine?

The X Prize's 10 finalists were announced in September 2014, and one of the front-runners and favourites is Scanadu, a medical technology company based at the NASA Ames Research Center in southern California. The group is led by Dr Walter de Brouwer, a Belgian inventor who says he wants to build a 'Google for health'. This would be a global shared 'brain' of digital health data that inventors, researchers, doctors and the public could all benefit from.

The device, the Scanadu Scout, is a vital signs monitor that takes your readings when you hold it to your left temple. In seconds, it measures your heart rate, temperature, oxygen saturation and blood pressure. It sends the data to your phone via a Bluetooth connection – allowing you to view and track your vitals wherever you are. If you add the Scanaflo, you can pee on a stick to test your levels of glucose, protein, leukocytes, nitrites and more.

## Power to the people

This concept is long overdue, de Brouwer says. "Shockingly, there hasn't been innovation in tracking your health at home since the thermometer."

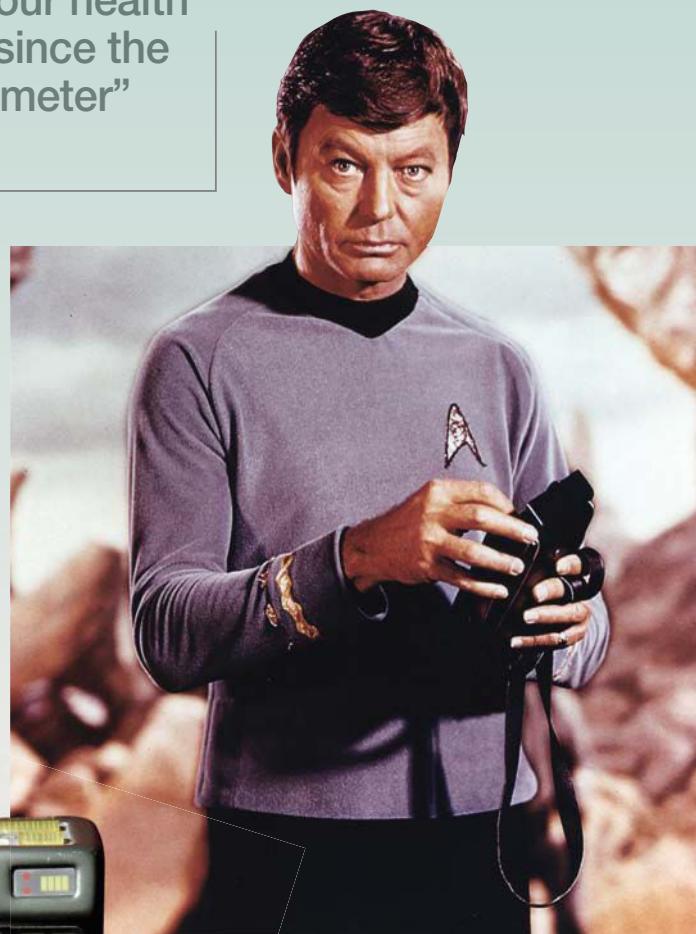
Being able to wave a device at someone and get potentially lifesaving information about their health could drastically shift the dynamic between medics and patients, and make amateur doctors of us all. You may be used to giving your symptoms a quick Google before visiting the doc, but a tricorder-style device could refine your knowledge and arm you with richer and more accurate data. "My goal is to make this the last generation to know so little about their health," de Brouwer states. And it seems the demand is definitely out there, as the Scanadu Scout raised more than US\$1.6m in funding during a 2013 crowdsourcing campaign.

Away from the prestige of the X Prize, there are other research companies quietly

"There hasn't been innovation in tracking your health at home since the thermometer"

Right and below:  
*Star Trek's* Dr McCoy  
and the show's vision  
of a medical scanner –  
the tricorder

Bottom right: Unlike its  
*Star Trek* equivalent,  
the Scanadu Scout  
has no display,  
instead sending data  
to a smartphone



working on modern tricorders. In the UK, the biotech company QuantuMDx makes diagnostic devices that the company says could play a role in addressing humanitarian health challenges, such as malaria, cancer and drug-resistant tuberculosis.

The jewel in QuantuMDx's crown is the Q-POC, a 'handheld laboratory' that analyses DNA and delivers the results of a battery of diagnostic tests in a few minutes. The device reads and sequences DNA and converts it into binary code using a tiny computer chip. The sequence is then ➔

# HOW DOES THE Q-POC WORK?

The first generation of the Q-POC will be built to detect malaria in blood, but the team is also working on other versions that could diagnose tuberculosis from spit. They are even considering a device that would be able to detect cancer in biopsies.

## 1. THE SAMPLE

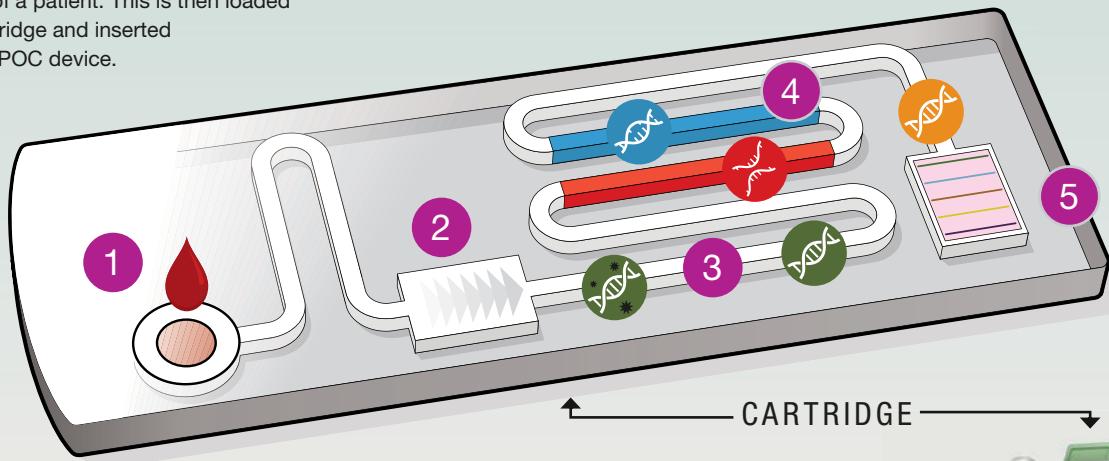
A drop of blood is taken from the finger of a patient. This is then loaded onto a cartridge and inserted into the Q-POC device.

## 2. BREAKDOWN

The blood is then broken down in a process called lysis. For this to take place, the sample is channeled into a chamber containing a small motor – the kind that makes your smartphone vibrate – that has a blade attached. This miniature blender breaks down the cells into a soup (called a lysate) containing DNA and the rest of the molecular junk, such as cell membranes and proteins.

## 3. CAPTURE

The DNA needs to be separated from all this molecular junk, so a special molecular filter is added. This gets rid of the all the rubbish, leaving only the genetic material behind. The traditional lab approach involves 'rinsing' the junk away from the DNA, which requires clean water and takes one to two hours. The Q-POC can do it in three minutes.

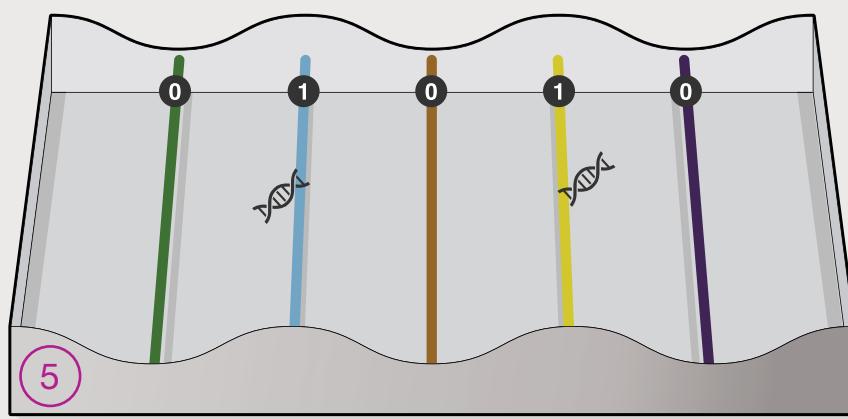


## 4. AMPLIFICATION

The DNA moves into a channel where it is heated and cooled. This separates the two strands of the DNA helix, allowing a special enzyme to copy the DNA. There could be lots of different strands of DNA from pathogens inside the sample; the enzyme is selected to only reproduce the DNA sequence relating to one disease, in this case malaria.

## 5. ANALYSIS

This solution is passed over a series of nanowires embedded onto a chip. The wires are so tiny that 100,000 could be squeezed onto a human hair. These wires act as biosensors. Malarial DNA binds to the wire when it passes over it, causing a change in resistance. This tells the Q-POC that malaria is present. The whole process takes 15 minutes.



## THE FUTURE

Without Q-POC, a sample would need to be sent to a lab, wasting days at a time. The traditional process takes a lab technician an entire day to complete. The goal is for the Q-POC to be able to test specific symptoms. If a patient reported a fever, for example, a cartridge could confirm that the pathogens responsible for inducing fever were present. The company also hopes to charge the Q-POC with solar-powered battery packs so testing can be done even if electricity isn't available. The system doesn't require water, making it perfect for helping deliver treatment to developing countries.

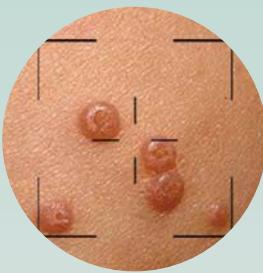
# PATIENT, HEAL THYSELF

Can't wait for your tricorder? These high-tech health helpers are available now



## 23andMe

23andMe's test analyses the DNA in saliva and tells you if you're at low, typical or high risk of diseases such as Alzheimer's and Parkinson's. It also tells you if you have genes that are linked to inherited conditions like cystic fibrosis.



## First Derm

If you've got a skin complaint that you're concerned about, simply snap a picture, fill in a form and send it off to First Derm via the website or the iPhone app. Within 24 hours a dermatologist will let you know what to do next.



## Cloud DX Pulsewave

The Pulsewave is worn as a wrist cuff so you can check your heart rate and blood pressure, and test for heart anomalies. The data is stored by Cloud DX and can be accessed and tracked, allowing you to look for trends and patterns.



## Peek Vision

The Peek Vision app and adapter turns your phone into an eye examination kit. It can check visual acuity, scan the retina and identify cataracts. It gives quick and easy access to the tools needed to prevent blindness.



## Cardiio

The Cardiio app transforms your iPhone or iPad into a heart rate monitor. When your heart beats, more blood rushes to your face. Cardiio's software is able to detect these tiny changes when your device is held in front of you.



## Cellscope Oto Home

The Oto Home device is inserted into the ear, and the app guides you through the process of taking an examination. It'll offer a doctor's response in just two hours. At the moment, Oto Home is only available in California, but may be rolled out further.

translated into a simple message for the user to read and interpret what the DNA analysis actually means. You simply place a sample into the cartridge, insert the cartridge into the device and press 'Go'. In around 15 minutes your results are presented on the screen.

## Health helper

"The Q-POC does the work of four different machines in one handheld device and generates an output that can be used for diagnosis," explains QuantuMDx's chief executive Elaine Warburton. "It might sound like the sort of thing that you see on CSI Miami, but we took that technology, then re-engineered and miniaturised it into a cassette the size of a credit card."

The Q-POC can also be used to track outbreaks of infectious diseases, by sending up-to-the-second test results via GPS and mobile networks. In developing countries where resources and healthcare professionals are scarce, the impact of this kind of device could be profound.

The makers of both devices say that the aim is to eventually make their tricorders available direct to consumers. But both still need to be tested in clinical trials and approved for accuracy and safety by the US Food and Drugs Administration in the case of the Scanadu Scout, and by the UK CE marking body for the Q-POC before its slated soft launch in late 2016.

De Brouwer is convinced that giving everyone this level of information about their health is an empowering force for good. "Having that knowledge empowers you to have more informed conversations and more productive visits with your doctor," de Brouwer states.

And Warburton agrees with him. "We're working with clinicians on the nature of the output – the actual results the Q-POC generates on-screen. They need to be accurate, of course, but also presented in a way that is most useful to the user, be that a pathologist, a healthcare professional or Joe Public."

But there's scepticism from the medical community about whether the tricorder could ever be useful. Dr David Warriner, a member of the Royal College of General Practitioners' overdiagnosis group (and a *Star Trek* viewer in his youth), says the tricorder pretenders are some way off being diagnostic devices in the clinical sense. Warriner argues that when it comes to our health, more information →



Below: X Prize finalist the Dynamical Biomarkers Group created this tricorder concept with accessories that can test blood, breath and urine

Above: Elaine Warburton at Downing Street with an early Q-POC prototype

Right: The Scanadu Scout is held against the head to take health readings



is not always better. By giving everyone access to their health data out of context and without any medical counselling, it could mean that doctors are left to deal with the fallout from these devices when worried patients incorrectly interpret the results and rush to their GPs for reassurance. Nevertheless, de Brouwer insists that being aware of your health data can alleviate anxiety.

While Warriner agrees that the devices will empower patients, he cautions that one-off measurements are seldom of use. "It is

**"It is patterns, which emerge over time, that indicate the presence of significant pathology"**

patterns, which emerge over time, that indicate the presence of significant pathology. Simply measuring and recording the data is not enough," he explains. "If a test is negative, then there is a danger the patient will be falsely reassured and will then smoke, drink and eat to their heart's discontent. Or if it is positive, then a patient may live the rest of their life with the Sword of Damocles hanging over them."

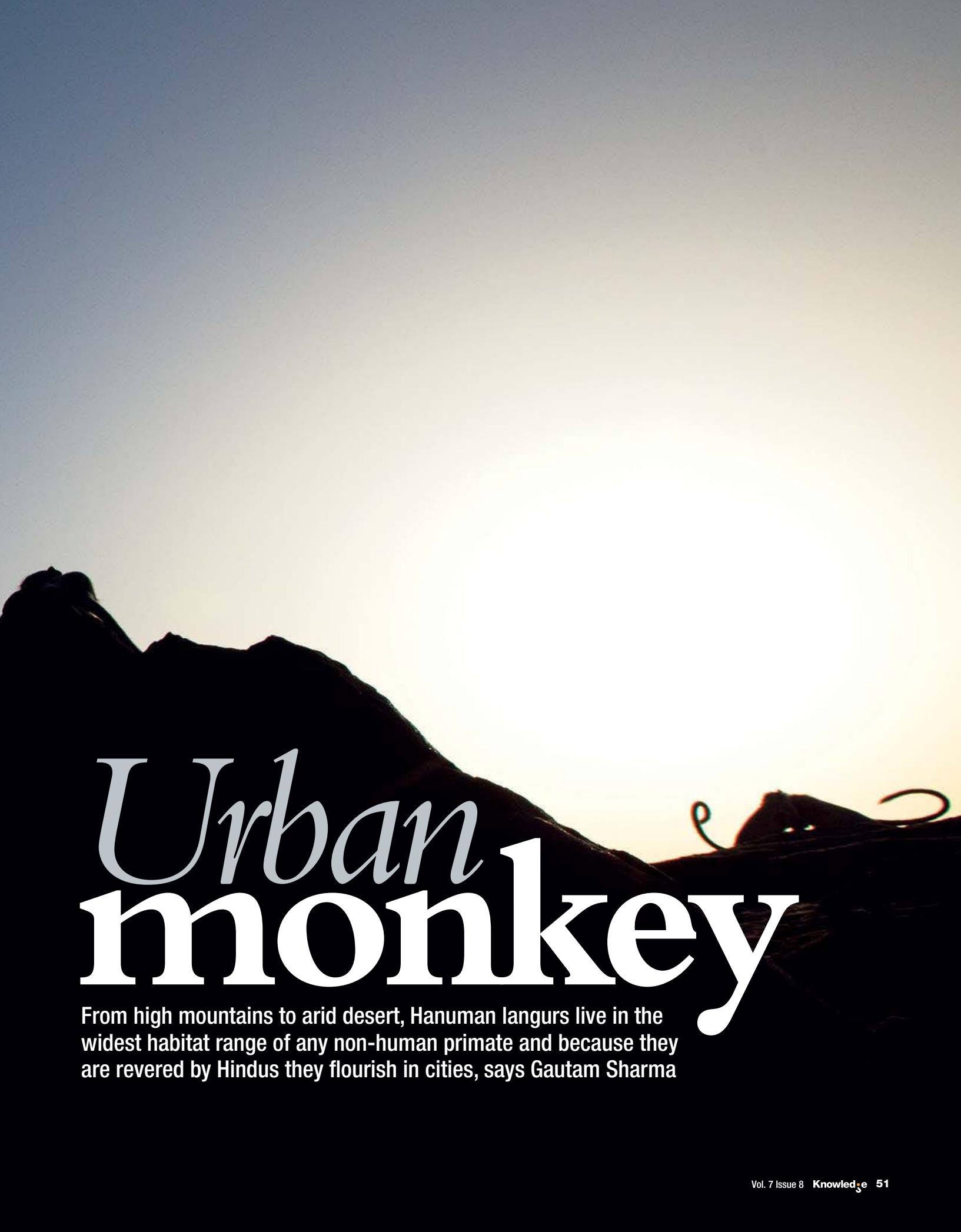
Despite the doubters, de Brouwer is convinced the potential for the Scanadu Scout is limitless. He states that consumers want to be more informed, so the potential market is huge. This is backed up by the diverse group of prospective customers that Warburton says is already interested in the Q-POC. These include Western governments interested in detecting biological weapons, forensic police units wanting them for crime scene investigations, and archaeologists identifying fossil species.

But it's in the medical field that a tricorder could really create a fundamental change in how we think about our health. Checking your symptoms online could become a vastly different experience, and it could soon be the norm for your GP to take a look at your symptoms with their smartphone. Dr McCoy would be proud. ■

**LILIAN ANEKWE** is a medical journalist and editor at *Pharmafocus*

An hour after sunrise this troop of about 100 Hanuman langurs *Semnopithecus entellus* run along a cliff edge outside the city of Jodhpur, in the Indian state of Rajasthan. The word 'langur' comes from the Sanskrit *langulin* which means 'having a long tail' – Hanuman langurs have longer tails than any other primate. Measuring up to 87cm, they have evolved to aid balance as the monkeys move through the forest canopy

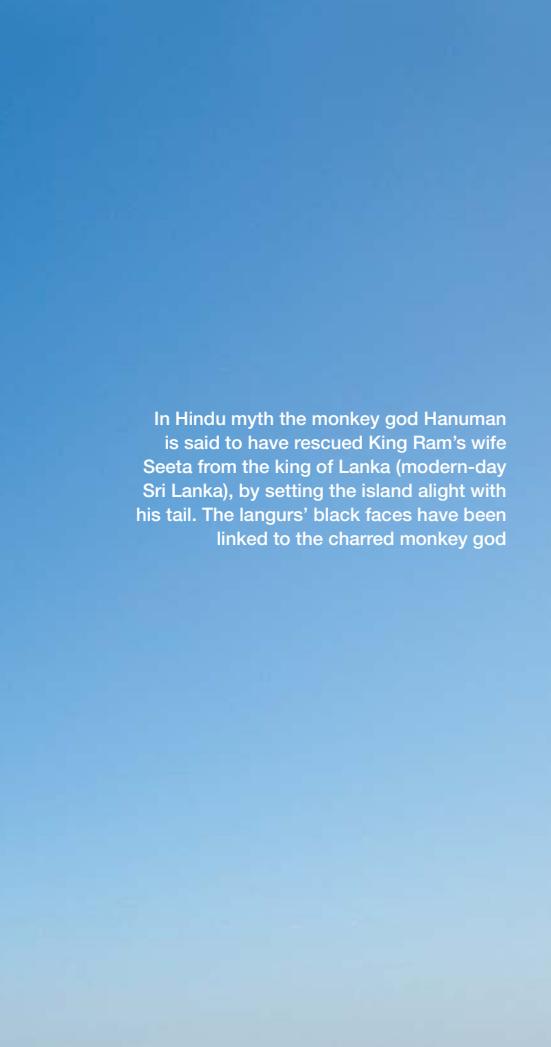




# Urban monkey

From high mountains to arid desert, Hanuman langurs live in the widest habitat range of any non-human primate and because they are revered by Hindus they flourish in cities, says Gautam Sharma





In Hindu myth the monkey god Hanuman is said to have rescued King Ram's wife Sita from the king of Lanka (modern-day Sri Lanka), by setting the island alight with his tail. The langurs' black faces have been linked to the charred monkey god

**FAR LEFT** This female is being groomed by a subordinate female. It seems likely that a langur's rank is inherited from its mother. However, though hierarchy is important, researchers have seen subordinate females display a surprising level of aggression towards those of higher status when there is stiff competition for provisioned food

**LEFT** This troop are sitting on a cliff overlooking the suburbs of Jodhpur. There are an estimated 2,400 langurs in and around the city, organised in approximately 40 groups with just one adult male ('uni-male') plus 20 all-male groups. Urban troops tend to be smaller than those in more rural habitats

## PHOTOS BY

ANUP SHAH AND FIONA ROGERS



This husband and wife team of wildlife photographers have contrasting styles. Their work concentrates on various primate projects in the wilds of Africa and Asia, and has appeared in many international publications. [shahrogersphotography.com](http://shahrogersphotography.com)

**H**anuman langurs (or grey langurs) thrive around the city of Jodhpur on the fringes of India's Great Desert, thanks to the country's spirituality and legends. "The Hindu belief in the sacredness of all life and the weaving of monkeys into ancient mythology have helped to create a climate of tolerance," explains Gautam Sharma, a zoologist at Jodhpur University. The langurs are believed to be the descendants of the fire-wielding monkey god Hanuman, and are often treated as sacred beings.

So it's no surprise that urban langur troops tend to be bolder than their rural cousins, and their behaviour can alter dramatically as they move from one part of their range to another. In forested areas they forage for their natural diets of leaves, flowers and insects, but in the city the same troop will scavenge for leftovers and accept the food that people give them.

"We see a marked increase in social tension in the study groups during periods of provisioning in the city, which usually manifests as enhanced aggression among the adult females of the troop," explains Sharma. "Research into higher-provisioning troops found increased levels of aggression. Threats, chases and attacks were recorded up to six times more frequently during feeding periods."

In the wild the monkeys' sacculated (chambered) stomach allows them to break down a high-cellulose diet of leaves and unripe fruit, and troops living at over 4,000m in the Himalaya can survive on a nutritionally poor diet of bark and mature leaves. The very same morphology allows the langurs to survive the perhaps equally challenging diet they have in cities, though an unhealthy urban lifestyle does take a toll.

## THE LOCATION

**JODHPUR, RAJASTHAN**  
Jodhpur, the second-largest city in Rajasthan, is located on the edge of India's Thar Desert. Hanuman langurs can be seen throughout the city, often moving across rooftops. Their sacred status ensures their safety from persecution; in fact both tourists and locals feed the monkeys. There is also a plentiful diet of leftovers to be scavenged and food stalls to be raided.





Hanuman langurs can be found across the Indian subcontinent, in Sri Lanka, Bangladesh and Pakistan. Researchers have identified 170 plant species that they feed on around Jodhpur, though they increasingly eat processed food meant for humans. The monkeys are revered in Hindu society but will raid crops, and growing secularisation has increased the conflict between langurs and humans



ABOVE Langurs are often seen grooming cows, sheep and feral dogs. When the males of rival troops meet at territorial boundaries, there is a lot of running and chasing though physical contact is kept to a minimum. Dogs that have attached themselves to one troop often act aggressively towards the enemy group during these conflicts

LEFT Big Boy is the alpha male of his troop – langurs outside of a troop regularly test the dominant male to identify any weaknesses. If a new male takes over as alpha, his first move is often to kill any unweaned infants, which brings females into oestrus sooner. So females mate with a variety of outsiders to confuse the issue of paternity, because males do not kill their own offspring



ABOVE Juveniles within the troop are very playful. Males tend to leave their natal troop at about two-and-a-half years old, but females remain with the group and deliver their first young at around four years old

RIGHT The food that is offered by local people can impact on langurs' health, as can a lack of exercise – some females are overweight. Heart disease is prevalent and infections from human food have been identified. Tuberculosis has been found in the langurs, as well as the human SRV-6 virus

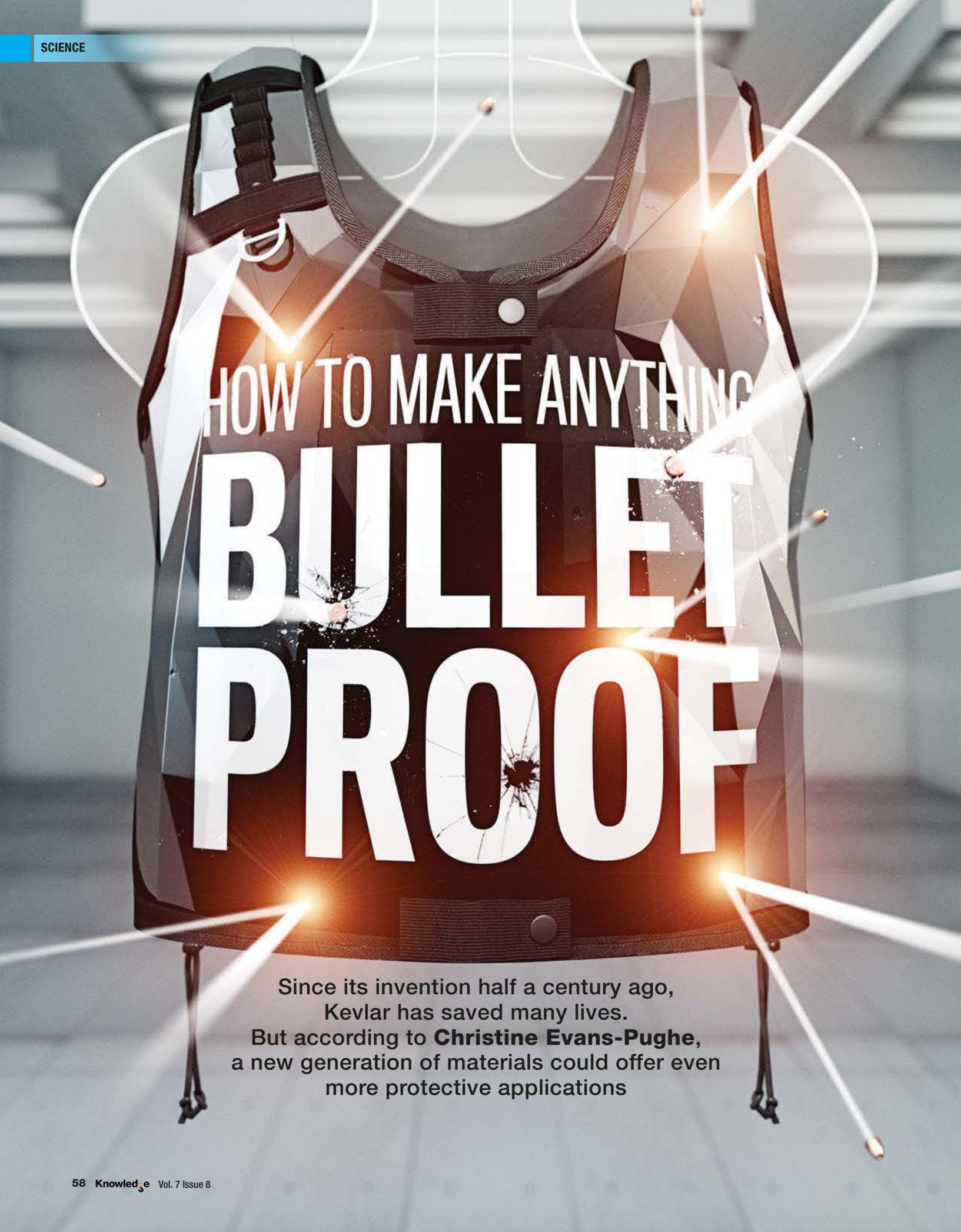




Births peak between February and April, when there is plenty of food after the rains. Babies have dark fur that turns a greyish gold after a few months, while their faces have pink skin that gradually darkens until it is black at 10 weeks of age. A young langur starts eating solid food when around three months old



LEFT Here the monkeys are foraging for plants and insects. Langur troops practise 'alloparenting', where females allow others within the troop to hold and care for their young, but the maternal bond is still strong. During his time studying Jodhpur's langurs Gautam Sharma recorded one older mother carrying her dead offspring for 27 days.



# HOW TO MAKE ANYTHING BULLET PROOF

Since its invention half a century ago,  
Kevlar has saved many lives.

But according to **Christine Evans-Pughe**,  
a new generation of materials could offer even  
more protective applications

**F**ifty years ago, a chemist working at DuPont in the US created a plastic that was light, flexible and seriously strong. In fact, Stephanie Kwolek had invented a substance that was five times stronger than steel of the same weight, making it tough enough to stop bullets and deflect blows from knives. Poly-paraphenylene terephthalamide, or Kevlar as it is more commonly known, has since been used in everything from bulletproof vests to soldiers' helmets. It's even used for protective shielding on the International Space Station. But half a century since its creation, can Kevlar keep up with advances in science and engineering to retain its crown as the go-to protective substance? Or will a new generation of materials allow us to make anything bulletproof?

Kevlar is a polymer. Polymers are substances made from a large number of repeating units – monomers – that are joined together. In Kevlar, these monomers are arranged in ring-like structures similar to those seen in benzene. It is this structure that is key to the material's properties.

### Bullets and benzene

"Kevlar was revolutionary because the chemical structure of the polymer chains forces them to align in one direction," explains Asa Barber, Professor of Advanced Materials Engineering at the University of Portsmouth. "If you think of a tangle of rope fibres as similar to randomly arranged polymer chains, these are easy to pull apart. But once you arrange the rope fibres side-by-side, the structure has great strength. That's how Kevlar works. The bulky benzene groups are also part of the deal. It's like having a series of big knots hanging off the sides of a piece of string – the string cannot be flexible because they stop it from bending. These 'side groups' also force the main chain to be ordered in one direction."

But for a material to be resistant to bullets, it also needs to be able to absorb energy over a large volume in order to spread out the impact of the force. Kevlar is a stiff, low-density material, so it does this extremely efficiently. To make a bulletproof vest from



A DuPont worker adjusts the valve on a Kevlar spinning machine

KEVLAR IS  
FIVE TIMES  
STRONGER THAN  
STEEL OF THE  
SAME WEIGHT



Kevlar is lightweight, yet it can still protect soldiers from bullets, grenades and fires

→ Kevlar, the polymer fibres are first spun into yarns and then woven into fabrics. Multiple layers of fabric are then hot-pressed with resin to form composites. You can boost the bullet-stopping ability by using finer yarns to make a closer-knit, denser fabric.

The protection works in three phases: first the bullet or fragment punches into the composite, then the impact causes the layers to start to separate and finally the fibres break to stop it. Together, these stages slow down and catch a projectile.

In circumstances where high velocity and armour-piercing bullets might be encountered, hard ceramic plates made from silicon carbide or alumina are added to bulletproof vests to cover vital organs. These panels squash projectiles on impact while the Kevlar absorbs the impact shock. In case you're wondering, you can't cover the whole

## "When hunting, the creature smashes its claw into its prey with the speed of a .22 caliber bullet"

body in ceramic material because it would be too stiff and heavy.

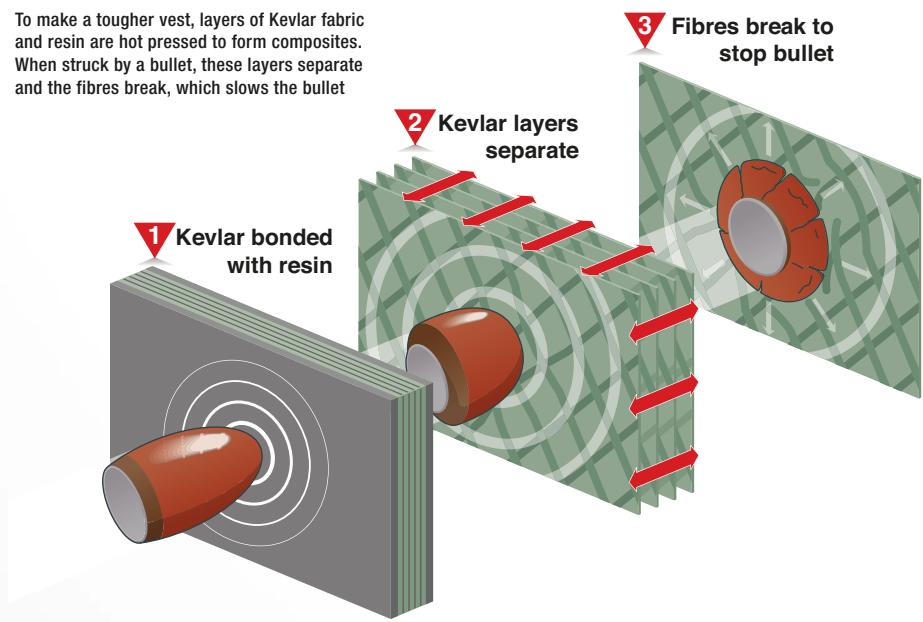
However, black diamond looks like it may well be the bullet-squashing ceramic of the future. Black diamond is also known as boron carbide and is the third hardest material on Earth (diamond and boron nitride pip it to the post). It has a density of 2.52g/cm<sup>3</sup> – in comparison, steel is 7.8g/cm<sup>3</sup> while Kevlar is 1.44g/cm<sup>3</sup>. So far, black diamond's downside has been its high price. But Dr Isaac Chang, an expert on materials processing at the University of Birmingham, has recently patented a way to make it much cheaper.

"Instead of heating the raw ingredients to 2,500 °C and then spending weeks grinding the resulting ingot [a block measuring 2.5m x 1.5m] into powder, this new process uses a temperature under 1,500°C," he explains. "By first dissolving the ingredients into a special solution, we get a precursor material that when heated results in a ready-to-use powder."



Kevlar thread can be woven into fabric to make light and strong body armour

To make a tougher vest, layers of Kevlar fabric and resin are hot pressed to form composites. When struck by a bullet, these layers separate and the fibres break, which slows the bullet





Kevlar fibres woven into fabric



Hagfish slime is being researched as a Kevlar successor



Imagine what this bullet could have done...

He's currently working with the US Army Research Laboratory (ARL) and the UK's Defence Science and Technology Laboratory (DSTL) on developing and testing this material for ballistic use.

### Fierce creatures

Designs inspired by the natural world are also looking like key players in the future of armour-plating. Prof Barber's group recently published work on goethite, which is an incredibly strong material found in the tiny teeth of limpets. Limpets rasp their strong teeth over rock surfaces to remove the algae on which they feed. The fibres of goethite are just the right size to make up a resilient, hardwearing structure, and could potentially be copied for use in high-performance engineering applications.

Another natural structure capable of resisting ballistic type impacts is the hammer-like claw of the peacock mantis shrimp. When hunting, the creature smashes its claw into its prey with the speed of a .22 caliber (diameter in inches) bullet. The crustacean's claw is made from an incredibly hard material and can withstand similar pressures to silicon carbide. However, it has the advantage that it can be formed at room temperature (or

# THE BIRTH OF KEVLAR

One chemist's discovery is used for body armour, motorcycling clothing and even oven gloves

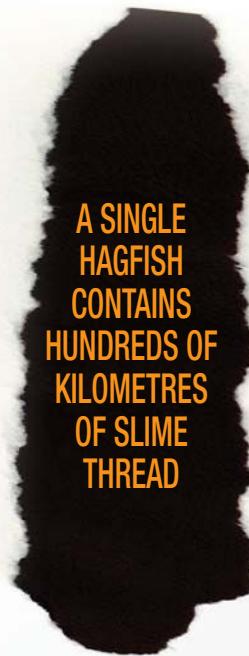


Stephanie Kwolek's invention keeps soldiers safe, but also protects keen cooks from burns

US chemist Stephanie Kwolek developed Kevlar in 1965 while working as a research scientist for DuPont. Kwolek specialised in low-temperature polymerisation, which is a process used to make plastics by linking together molecules known as monomers. During the

early 1960s she was given the task of looking for a lightweight but durable fibre that could be used in the manufacture of tyres. Many of the materials she created were too unstable to remain for more than a few seconds. But one combination caught her eye when it turned into a cloudy

fluid. This was in contrast to the clear, treacle-like form of most of the previously discovered polymers. When spun into a fibre, the material proved to be very strong. She realised at once that she had discovered something special. In 1971, her creation reached the market under the name Kevlar.



sea temperature...) rather than requiring the high temperatures of a furnace. The hammer has an impact region made of precisely aligned hydroxyapatite crystals. Behind this is an area of spiralling layers that act as shock absorbers. Each layer sits at a slightly different angle from the layer below and this helical structure prevents cracks from spreading. Last year, researchers at the University of California, Riverside, the University of Southern California and Purdue University received a \$7.5m grant from the US Department of Defense to develop this work further.

A number of research teams have also proposed novel successors to Kevlar. These substances are based on spider silk, graphene, nanocellulose and even the gloopy slime produced by a sea creature called a hagfish. Nevertheless, it is ultra high molecular weight polyethylene (UHMWPE)



# AMMO IN ACTION

Some of the high-tech weaponry that Kevlar and other bulletproof materials are up against



## HOLLOW-POINT BULLETS

These have a cavity on the front that makes them expand when they strike an object, creating more damage than a round-nosed bullet. This fragmentation also decelerates the bullet to reduce the penetration depth. While hollow-point bullets are banned for military use, they are widely used by police and law enforcement agencies in Europe and the US as a way of instantly stopping hostile subjects.



## XM25

This 25mm grenade is designed to explode into fragments. It is aimed close to, rather than at, the target and a timed fuse tells it when to explode based on the calculations of a small computer located inside the grenade.



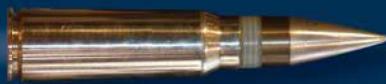
## EXACTO

DARPA has developed this device for snipers. It uses a real-time guidance system to change its path and home in on a target. Inside the .50 caliber round is an 8-bit computer, which steers the device by moving small fins attached to its body.



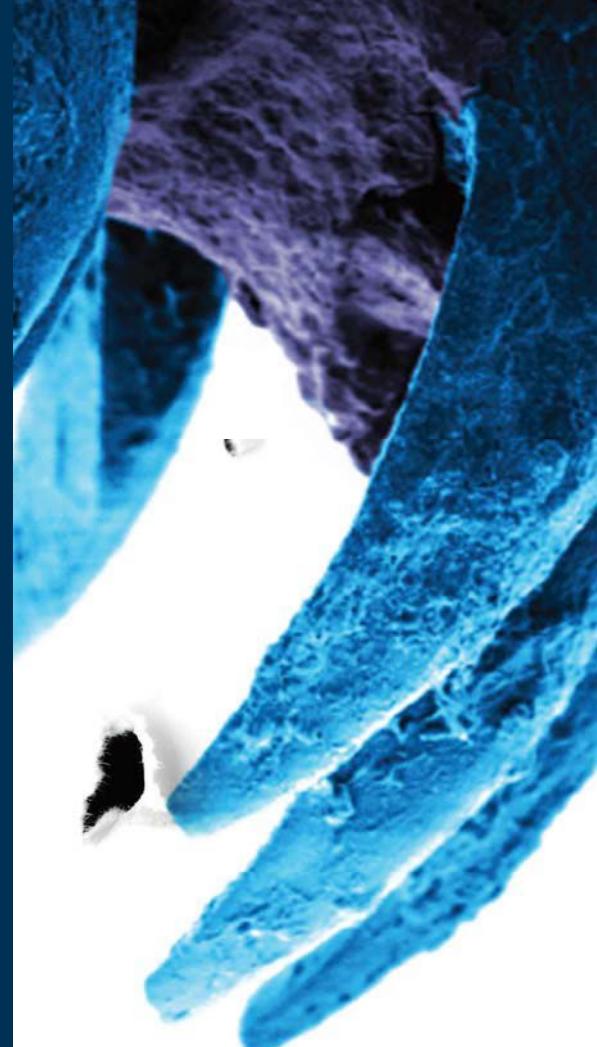
## ARMOUR-PIERCING BULLET

These are generally created for rifles and pistols. They have a pointy penetrator that's usually made from tungsten, tungsten carbide or steel. The high-density material is designed to keep its shape to carry the maximum quantity of energy deep into the target.



## DEPLETED URANIUM BULLETS

These are pyrophoric, which means that they ignite spontaneously in air. They are self-sharpening on impact, resulting in intense heat and energy focused on a minimal area of the target's armour.



**“The project involves building computer models of all kinds of ballistic materials down to an atomic scale”**

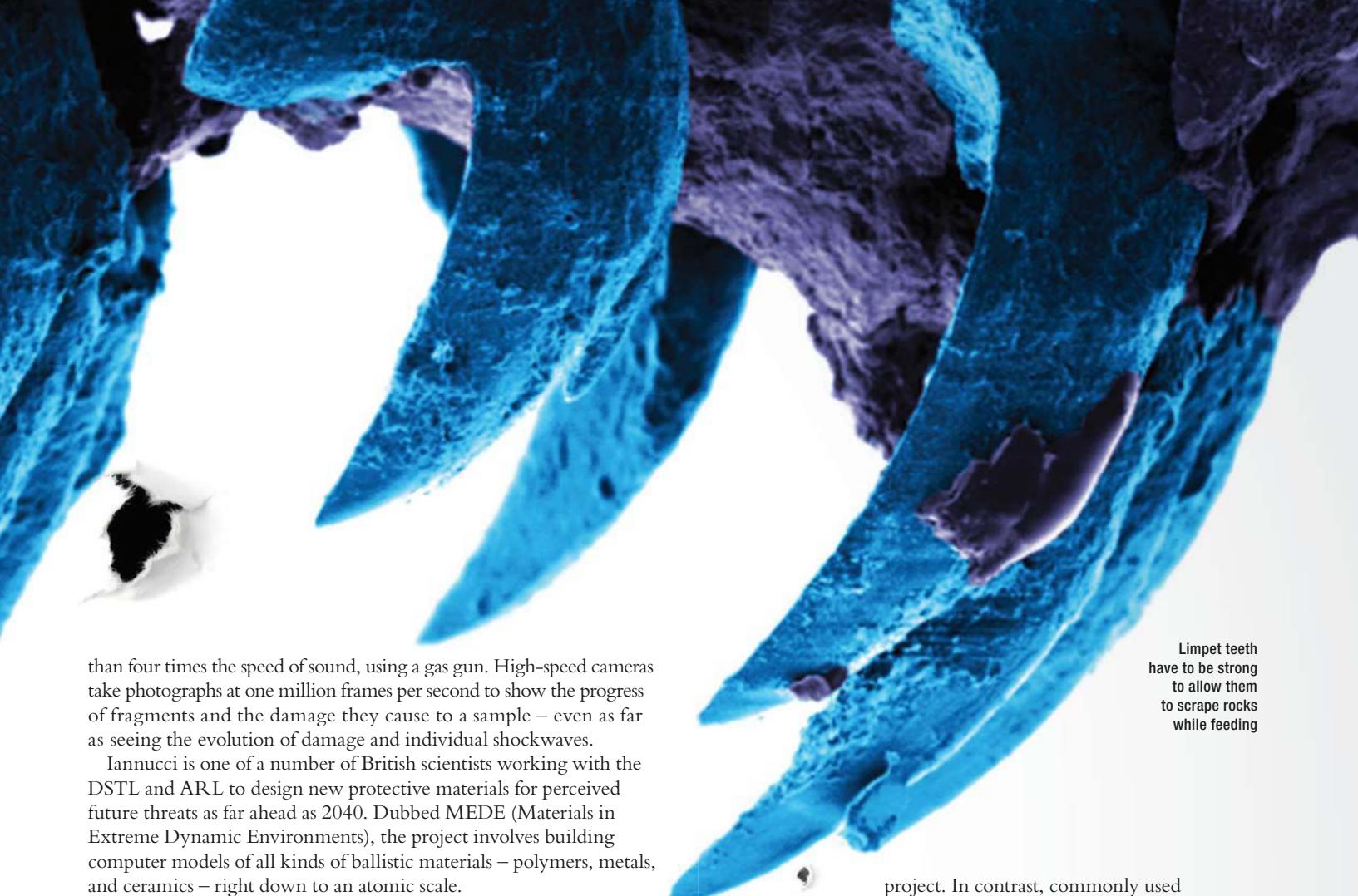
that is gaining the most attention. UHMWPE is similar to the polymer used in plastic bags. But whereas the polymers in bags are arranged in a higgledy piggledy fashion, the fibres in UHMWPE are spun from a gel to stretch and align the strands. Made in this way, the material has a strength-to-weight ratio 8 to 15 times higher than steel, although one disadvantage is that it starts to break down at temperatures over 130°C.

UHMWPE could be made even stronger if the lengths and ends of these aligned polyethylene molecules (the fundamental building blocks of the

US MILITARY HELMETS CONTAINS 19 LAYERS OF KEVLAR

fibres) were ‘tidier’, explains Lorenzo Iannucci, Royal Academy of Engineering Chair in multi-scale armour design and Professor in Advanced Aerospace Structural Design at Imperial College. “They currently look like curly spaghetti, which weakens the structure. Everyone is looking to gain better control of the mass production process to improve this. If this was possible, we could raise the strength of the fibres two-fold,” he says.

Iannucci’s laboratory has facilities to fire projectiles with speeds up to 1,400m/s, more



Limpet teeth  
have to be strong  
to allow them  
to scrape rocks  
while feeding

than four times the speed of sound, using a gas gun. High-speed cameras take photographs at one million frames per second to show the progress of fragments and the damage they cause to a sample – even as far as seeing the evolution of damage and individual shockwaves.

Iannucci is one of a number of British scientists working with the DSTL and ARL to design new protective materials for perceived future threats as far ahead as 2040. Dubbed MEDE (Materials in Extreme Dynamic Environments), the project involves building computer models of all kinds of ballistic materials – polymers, metals, and ceramics – right down to an atomic scale.

### Dress to impress

“We want to be able to simulate the performance of an entire ballistic vest based on models that came from information at an atomic level,” explains ARL’s Dr John Beatty, who is in charge of the MEDE



Dr Isaac Chang has patented a cheaper way to make boron carbide

project. In contrast, commonly used computer models of ballistic performance are currently based mainly on experimental data. This data comes from firing bullets at various materials rather than knowledge of how atoms behave.

Beatty’s researchers have recently made a breakthrough in developing fast and accurate equations for how individual atoms in polymers interact. This makes it feasible to simulate millions of polymer atoms interacting at once on a computer. Previously, it was only possible to look at roughly a thousand atoms in this way.

“These new models seem very accurate when we compare them with quantum mechanical calculations as well as with experimental data,” says Beatty.

The US Army Research Laboratory’s own polymer processing plant will be starting up this year. In 10 years, Beatty expects to have developed the fundamental science for designing most classes of protective materials. But what of the threats Beatty and his colleagues are expecting to be combatting in 2040? They’re classified. ■

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**CHRISTINE EVANS-PUGHE** is a science and technology journalist who has written for *The Guardian* and *The Economist*

# MICROBES ON THE MOVE

A new study paints a surprising picture of the microbes found around the home. Tom Ireland discovers that each family has their own personal zoo of bacteria...

**H**uman beings are increasingly seen by scientists as walking microbial ecosystems. Our bodies contain up to 10 times as many bacterial cells as human ones, and we each deposit a unique blend of bacterial cells everywhere we go.

Microbiologists are only just beginning to understand how the trillions of organisms that live in and on our bodies affect our digestion, immune response and behaviour. And an emerging area of study is looking at how bacteria we deposit around us interact with the buildings we inhabit. After all, some studies suggest people now spend between 22 and 23 hours a day indoors – and nearly 70 per cent of that time is spent in our homes.

Researchers from the Home Microbiome Study recently assessed the microbial communities associated with seven families and their homes over six weeks, including three families that moved house. They found that we quickly spread our own ‘microbial signature’ throughout the places we live. By sequencing the DNA of bacteria in the home, the researchers were able to create a picture of the genetic diversity of microbes in each environment – its

‘microbiome’ – and compare how genetically similar bacteria were to those found elsewhere.

The bacterial flora of each household was so unique that researchers were able to accurately match individuals to their dwellings – even when their ‘home’ was in fact a hotel room they’d only recently moved into. Not only did all the houses contain very different bacteria from each other, the study also showed that when families moved, their microbial signature quickly re-established itself in the new location.

Simon Lax, a co-author of the study from the Department of Ecology and Evolution at The University of Chicago, says the reason our bacteria dominate the places we live is simply because there are few other routes by which bacteria enter those buildings. “Almost all of the bacteria in the home can be traced back to the inhabitants. If you have humans constantly coming into a home, then they are the most common source of bacteria,” he says.

What’s more, obsessive cleaners might want to rethink their strategy: the study suggests that the more people potter around the house cleaning, the more bacteria they





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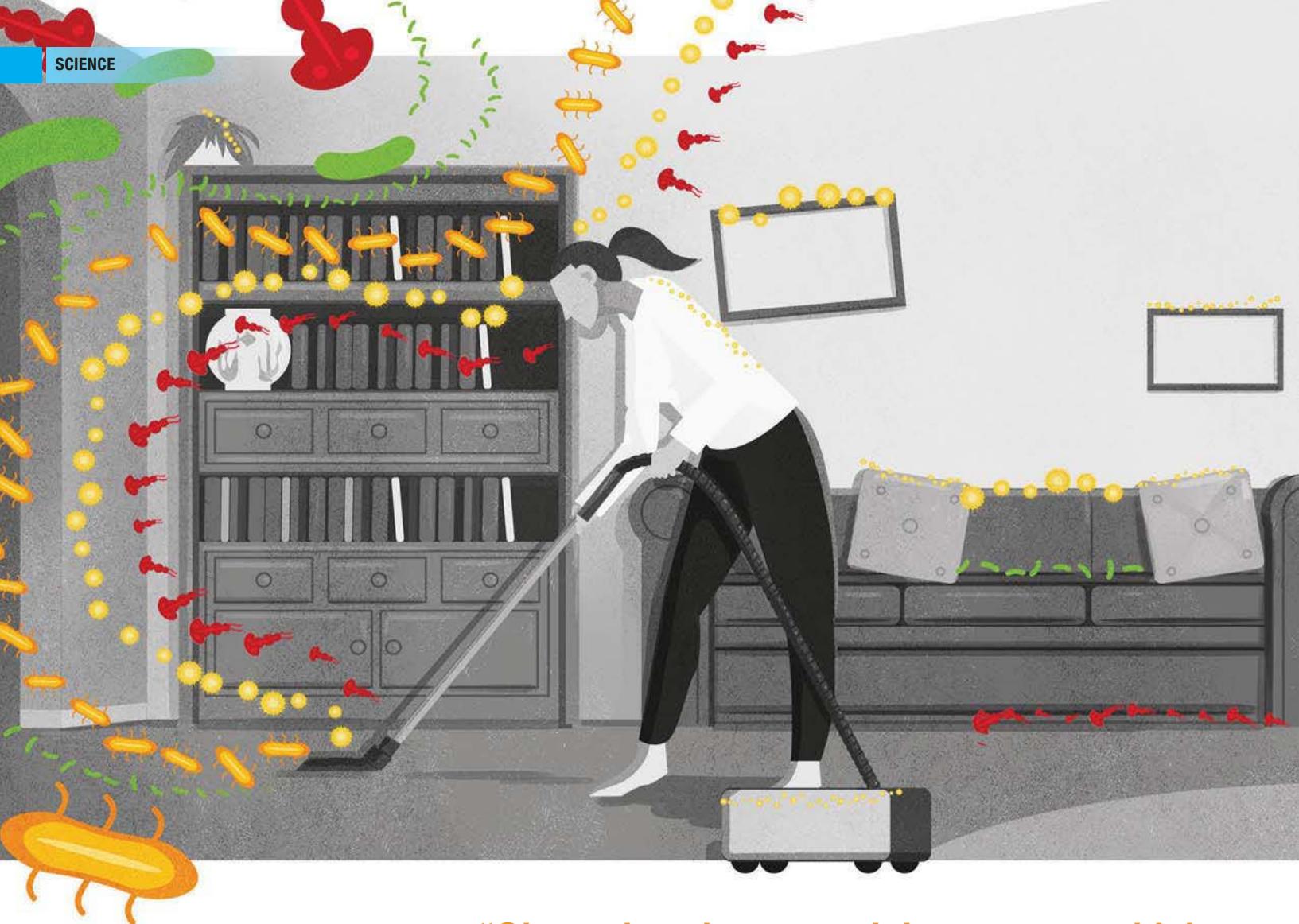


PHOTO: BIOLOGY & BUILT ENVIRONMENT CENTER/UNIVERSITY OF OREGON/CAMERON SLAYDEN/COMSMOCYTE ILLUSTRATOR: ROBIN BOYDEN

deposit. The best thing they could do to reduce the amount of microbes in their homes, Lax says, is not be there. "When you think of what people's homes are made from, they are mostly relatively new materials that bacteria haven't evolved to live and thrive on. These homes would normally have quite a low bacterial biomass until someone comes in," he says.

The idea of stepping into someone else's house, knowing it's teeming with the microbes of its inhabitants, may be unsettling to some. The way we constantly share microbes with people is something few people think about, but anyone spending a long time in a room full of people is likely to come out with a microbial flora more like the crowd's than their own. However, it might also be strangely comforting to know that the bacteria in any room you inhabit is likely to be 99 per cent 'yours' within 24 hours of you moving in. "The colonisation of a room is almost instant," says Lax. "Then a few days after a family leave, their bacterial signature diminishes again."

As part of the study, researchers took thousands of samples from inhabitants' noses,

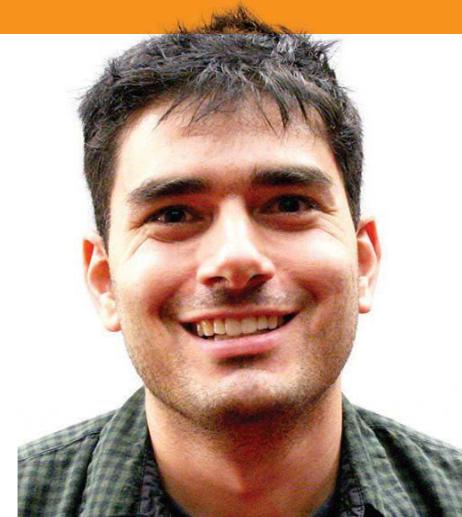
## "Obsessive cleaners might want to rethink their strategy: the study suggests that the more people potter around cleaning, the more bacteria they deposit"

hands, and feet, and from various places in their homes: the kitchen floor, worktop and light switch, the bedroom floor, bathroom doorknob and front door.

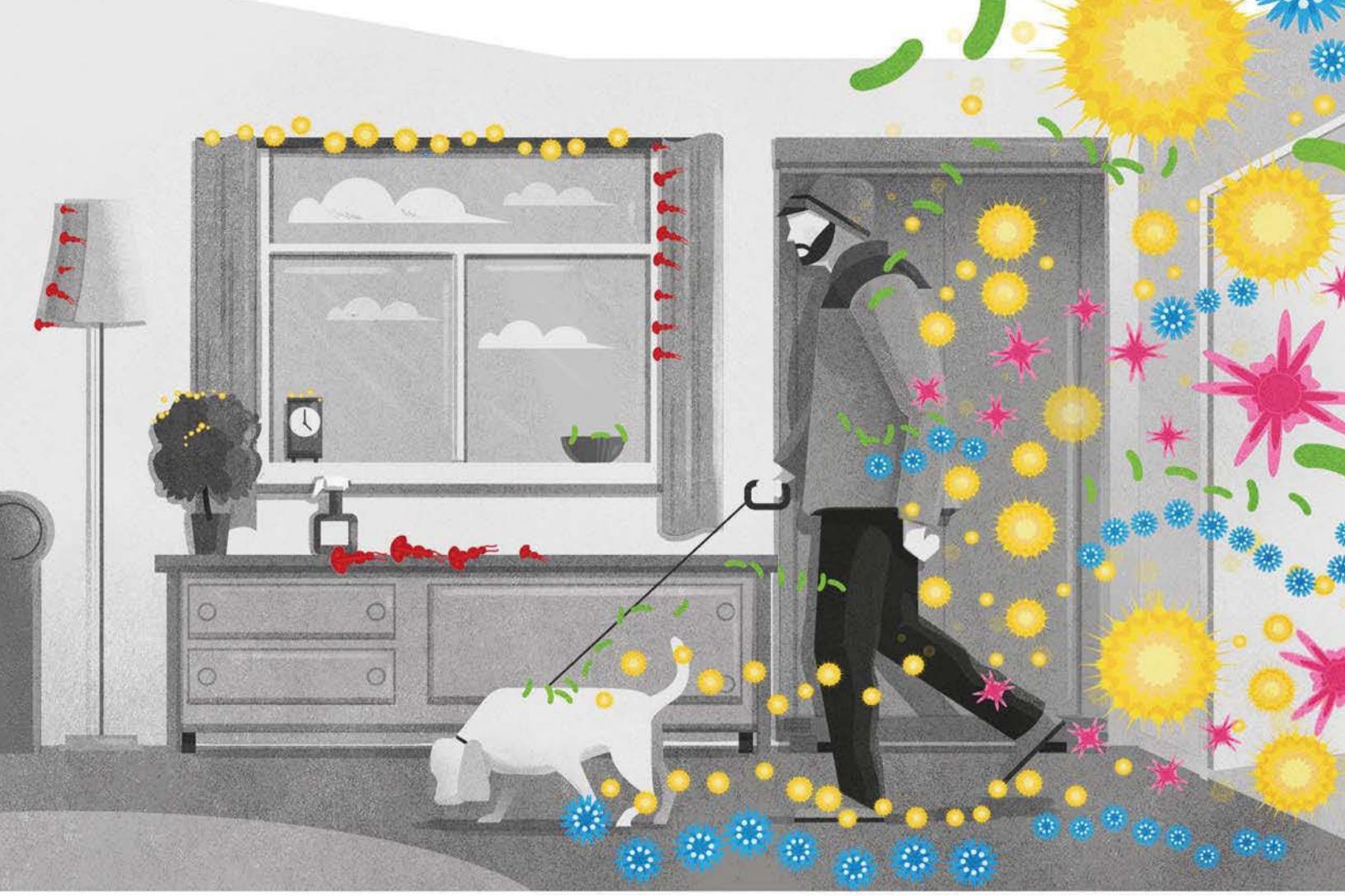
We may like to think certain places in our houses are cleaner than others, but the team actually found that different places within family homes were more alike microbially than the same locations in different houses. In other words, the bacteria on your kitchen table are more similar to the ones in your bathroom than the ones on your neighbour's kitchen table.

### It's a family affair

Who we live with and what we do also plays a key role in determining which bacteria take up residence in our homes. The study found



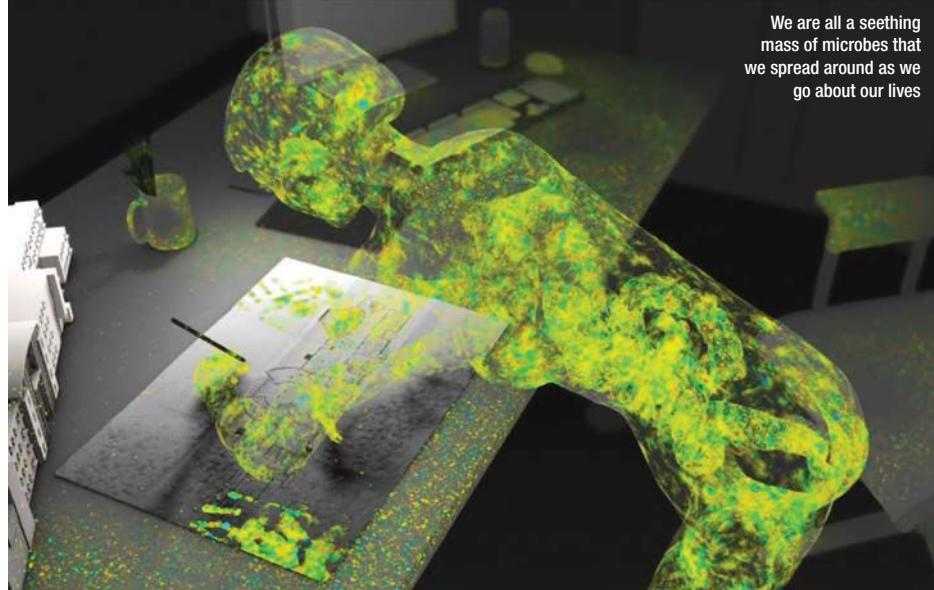
According to Simon Lax at The University of Chicago, we can only reduce the microbes in our home by not being there



that people sharing a home are more microbially similar to each other than those not sharing a home. The hands of young couples and couples with children were especially similar, thanks to regular physical contact. But there's one area of the body where we are each more individual: the nose.

"The nose is fairly stable environment that may be more unique to each person," says Lax. "But for places like the hand, it really comes down to what you've been in contact with, what you do for a living, who you've met, whether you live in the country or in the city. It's more of a lifestyle thing than anything genetic."

Although the bacteria found on people and their homes were always highly correlated, houses were not necessarily closely matched with the bacteria of their pet. The presence of a pet does, however, hugely expand the diversity of bacteria found in a home. Samples from homes with pets contained more proteobacteria, a class of microbe that contains many well-known pathogens including *Salmonella* and *E. coli*. While that may sound like a bad thing, the more we understand microbial diversity the



more we find that it helps us in more ways than it harms us. Exposure to varied bacteria at a young age is important for the development of a healthy immune system, for instance.

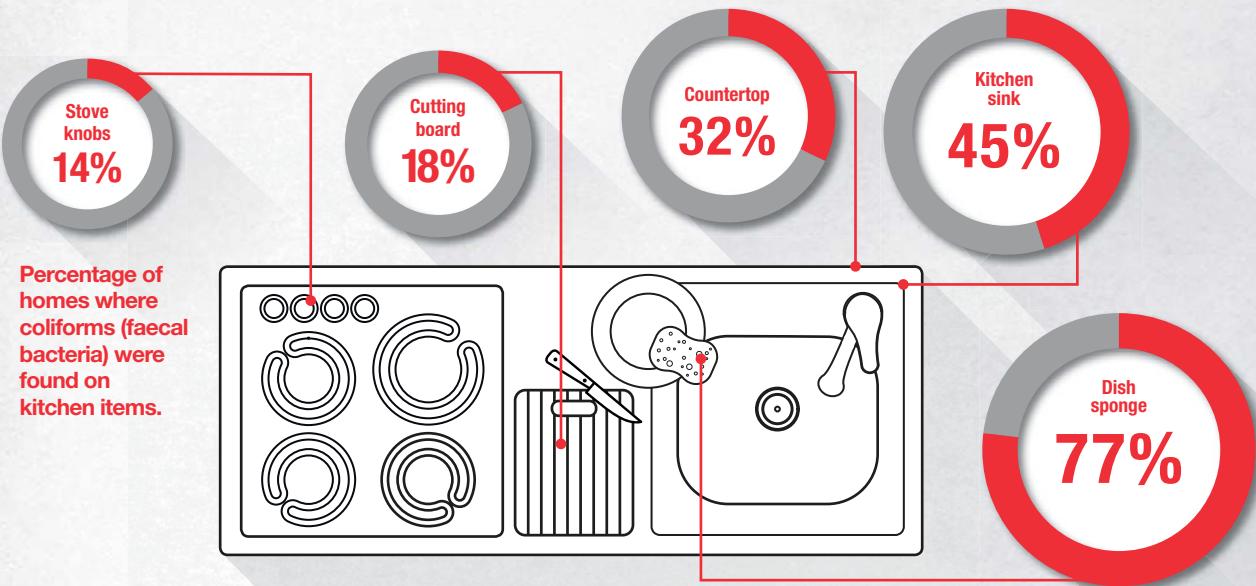
"It's not really a case of one house being

more unhygienic than the other," says Lax. "But what we know isn't good for babies and young children is only experiencing the microbiome of their own environment and the bacteria of their parents," he says. It's a bewildering concept – not only



# MICROBIAL HOTSPOTS IN OUR HOMES

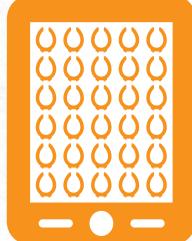
Our perception of hygiene often bears little relation to the reality of what microbes live where. Here's a rundown of some of the most colonised areas



# 10X

more bacteria is in the human digestive tract than there are cells in the human body.

An iPad typically houses 30 times more *Staphylococcus aureus*, the bacteria that can cause MRSA, than a toilet seat.

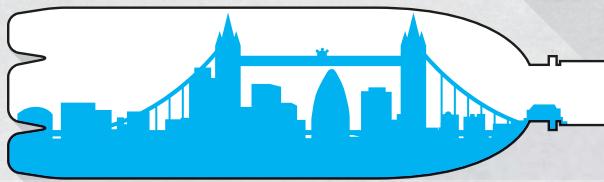


One sneeze can increase the amount of *Staphylococcus aureus* in the air by five times.



# 1,000,000,000,000

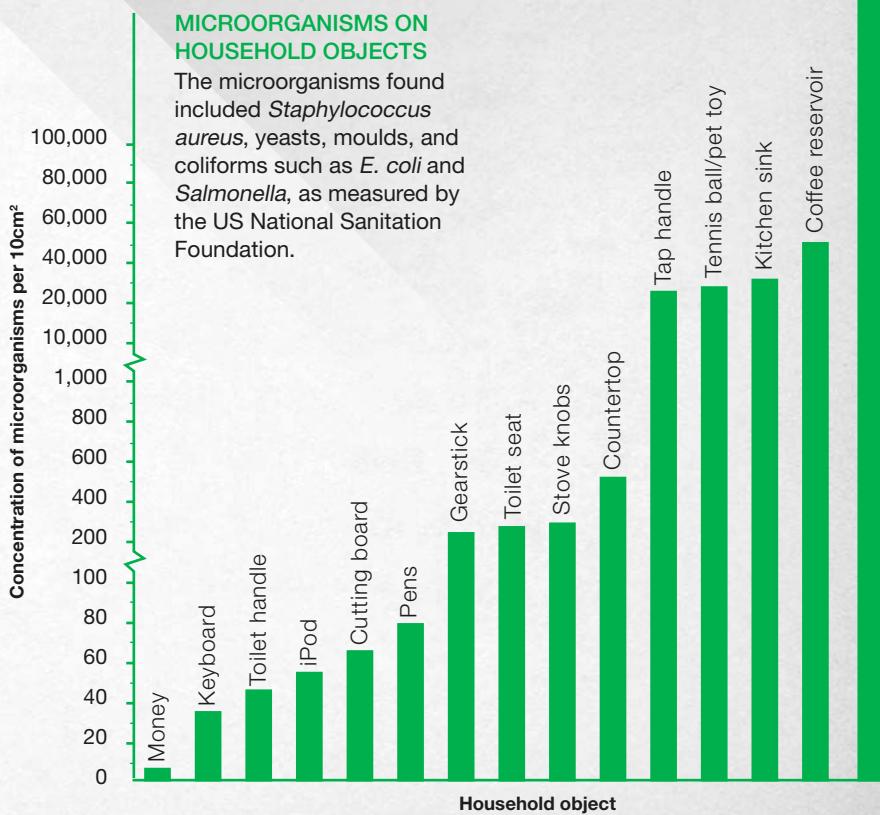
bacteria are harboured on human skin, which is 10 per cent the total number of cells that make up the human body.

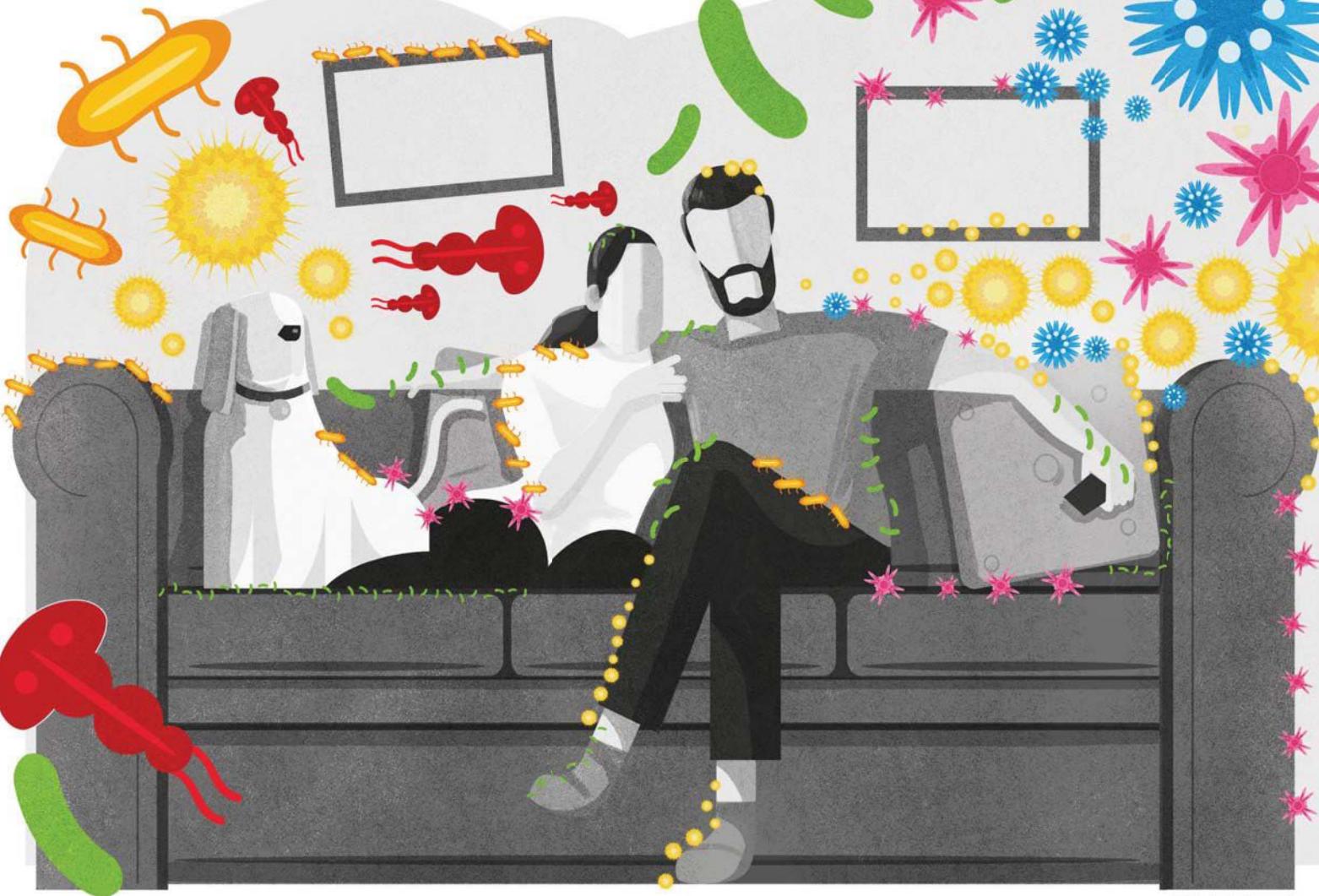


1.5ml of human saliva has 150 million bacteria – equivalent to the amount found in one litre of Thames water.

## MICROORGANISMS ON HOUSEHOLD OBJECTS

The microorganisms found included *Staphylococcus aureus*, yeasts, moulds, and coliforms such as *E. coli* and *Salmonella*, as measured by the US National Sanitation Foundation.





## **“What we know *isn’t* good for babies is only experiencing the microbiome of their own environment and their parents”**

**Simon Lax, Department of Ecology and Evolution, University of Chicago**

→ that we are covered head to toe in this strange microbial mixture, but that it might actually be a vital part of a growing family’s health.

The Home Microbiome Project is the first study to try to see families, their microbes and their homes as complex interacting ecosystems. Research has traditionally focused on where and for how long bacteria survive in the home, and also how to eradicate them. This new approach may contribute towards a fuller understanding of what a healthy home is – for example, what levels of bacteria can help develop a healthy immune system and what levels may constitute a health hazard.

The team’s next aim is to scale up its investigation and survey the microbiome of hospitals. “We are now taking this

approach and applying it to environments where the health implications are much higher,” says Lax. “We’ve seen hospitals with identical layouts and identical cleaning methods, so it can only be the different people that affect the bacterial samples found there. And in a hospital environment, there really are such a thing as good and bad microbiomes.”

### **A new understanding**

As our understanding shifts from a fear of all bacteria to an understanding of their role in ecosystems, our approach to tackling infection is likely to change. Attempts to simply wipe bacteria away seem increasingly futile. Indeed, some bioscience companies believe sprays containing ‘good bacteria’ may

be a more effective way of preventing dangerous human pathogens from taking hold in certain places.

More projects measuring the impact of microbes in the built environment are planned. Some even involve architects, who hope that future buildings can be built to encourage a healthy microbiome, or species that absorb pollutants from the air.

For Lax, the results of his study have opened his eyes to the unseen microbial mark humans make wherever they go. “I’m not grossed out by it, but it definitely makes you think. Am I leaving my signature behind when I visit this house? Am I changing what bacteria live here?”

In time, perhaps we will all come to see our house’s bacteria not as dirty intruders, but welcome guests – perhaps even tiny members of our extended family. On the sofa tonight, sit back and relax in the knowledge that it’s just you, your family, and a trillion bacteria that seem to enjoy your company in particular.

It’s true what they say – there really is no place like home. ■

**TOM IRELAND** is managing editor of *The Biologist*, the Society of Biology magazine

# THE BLACK

## THE HISTORIANS' VIEW

Was it inevitable that plague would sweep Europe in the Middle Ages? How long did it take sufferers to die? And what was life like in its aftermath? Here, a panel of experts reflect on some of the big questions of a disease that repeatedly ravaged Europe over hundreds of years

Words by Charlotte Hodgman

Two women do the 'dance of death' in a 15th-century woodcut. "The grim reaper of the plague stalked Europe for centuries, breaking out like earthquakes, unheralded and randomly," says Professor Tom James



# DEATH

**Carole Rawcliffe**

is professor emerita of history at the University of East Anglia. She co-edited *Society in an Age of Plague* (Boydell Press, 2013) with Linda Clark

**Tom James**

is professor emeritus in archaeology and history at the University of Winchester. His books include *The Story of England* (Tempus, 2003)

**Mark Ormrod**

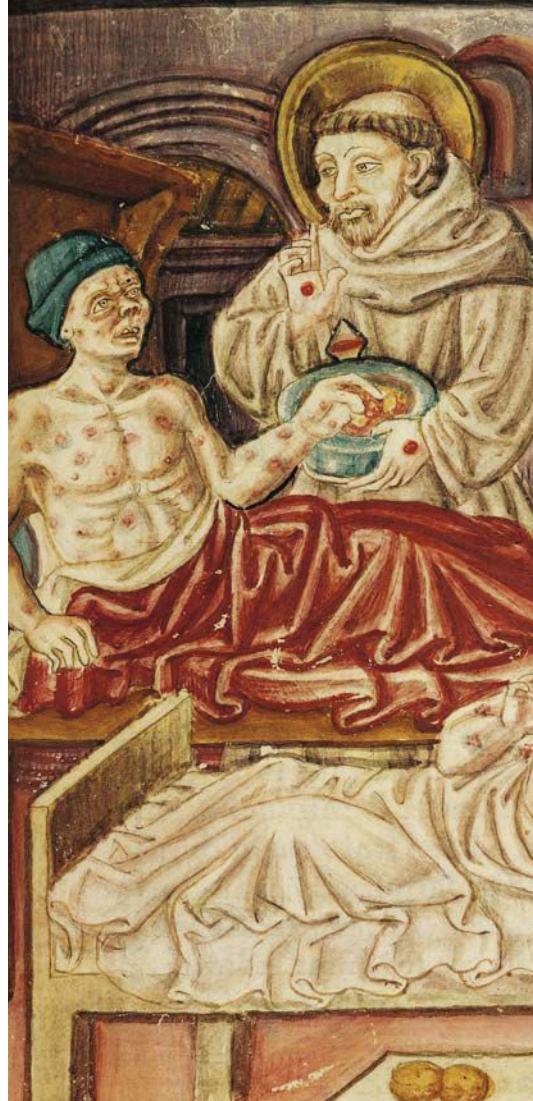
is professor of history at the University of York. He co-edited *The Black Death in England, 1348–1500* (Paul Watkins Publishing, 1996) with Phillip Lindley

**Ole Jørgen Benedictow**

is professor emeritus at the University of Oslo. He is author of *The Black Death 1346–1353: The Complete History* (Boydell Press, 2012)



People flee London during the Great Plague of 1665 in a contemporary illustration. That same year, the disease killed 260 out of 350 residents of the Derbyshire village of Eyam



### Was an epidemic like the plague inevitable during the medieval period?

**Ole Jørgen Benedictow:** No, it was not inevitable, but the requirements for its arrival and devastating long-time presence in Europe increased with rising population density and local and regional trade.

The development of long-distance trade by galleys and cogs from the late 1200s was crucial to plague's spread, because it linked Europe together and with distant trading stations and commercial hubs near plague focal points in north Africa, the near east, the Middle East, and in southern Russia. In the

early 1300s, the probability that plague would arrive in Europe was rapidly increasing; the commercial and demographic requirements for its dissemination were all in place.

**Mark Ormrod:** Some people have a deterministic view of population history, believing that, in pre-industrial societies, population generally tended to grow at a faster rate than the economy and that some external factor – be it famine, disease or war – would then intervene to re-establish the balance. There is plenty of evidence that parts of Europe were becoming 'calamity-sensitive' around 1300 and that the plague acted to restore equilibrium. But this is a long way from saying the plague, in its form and timing, was a historical inevitability.

**Carole Rawcliffe:** Famine-related epidemics were a fact of life for people who lacked the benefits of modern medicine and whose levels of resistance were often compromised by poor diet and unhygienic living conditions, as well as by endemic diseases such as tuberculosis and malaria. Several serious outbreaks of infectious disease are recorded across Europe in the decades before the Black Death, and although none rivalled it in severity, there can be little doubt that conditions favoured the spread of a major pandemic.

**Do we know how many people actually died from the Black Death in the 14th century?**

**“Rising population density and growing trade made Europe vulnerable to the arrival of plague”**

Ole Jørgen Benedictow

**MO:** It is agonisingly difficult to get good population data for medieval Europe: even for England, where the information is especially rich. No one took death tolls so we have to develop models of mortality from sources like clergy lists, manor court rolls and tax records. The conventional view is that around a third of the population of Europe died in the first outbreak of the plague between 1347 and 1350. But it returned on a regular basis and became endemic for the following 300 years.

The second outbreak of the Black Death, in the early 1360s, became known as the children's plague because of the high mortality among the generation born since the first visitation. By the end of the 14th century the population of some parts of Europe may have been only half what it had stood at two generations earlier.

**CR:** Local studies prove instructive when ascertaining the death toll. In cities like Norwich, where we have a reasonably good idea of population levels before and after the first two national epidemics (about 25,000 in 1330 and around 8,000 in the early 1370s), mortality seems to have been sufficiently high



Franciscans treat plague victims in an Italian illustration from c1474. Religious guilds proliferated in the wake of the Black Death, offering care both to the afflicted and to lonely, destitute survivors

**“Panic, flight and the mass burial of abandoned corpses were all common responses to the outbreak”**

Mark Ormrod

Evidence from London suggests that at first the dead were buried in coffins. As the disease got worse the bodies were placed in pits. However, the excavations show that the bodies were laid out in orderly rows with respect. A pit in Hereford, by contrast, is suggestive that the bodies were thrown in more higgledy-piggledy. Elsewhere, contemporary evidence from Rochester relates that the pits were left open and the weeping parents brought their children to the open pits and laid their bodies there.

**CR:** Levels of care varied dramatically from callous disregard to selfless devotion, although fear that the disease might be communicated through the gaze, breath or even the clothes of victims made most people understandably wary about close contact. In continental Europe (but not England), towns and cities engaged the services of surgeons and physicians whose duty was to care for the sick, but who sometimes took flight at the first sign of infection. In Italy, religious guilds undertook to provide support for the sick poor and the many destitute widows and orphans who were left behind after each epidemic.

**What was life like for the survivors of the Black Death?**

**TJ:** Medieval people knew what to do in time of plague and other disasters. Disposal of bodies in pits is well attested from earlier disasters, for example a volcanic eruption in the tropics in 1258 that led to widespread famine in Europe. More than 10,500 skeletons have been recovered from the Spitalfields market area of London alone since the 1990s, probably a proportion of a higher number dating to that disaster.

There were set prayers and Bible extracts

to justify at least some of the claims made by contemporary chroniclers. Florence, which is better documented, lost about two-thirds of its inhabitants in 1348 alone, but staged an effective demographic recovery. By contrast, many German cities escaped untouched.

**OJB:** My research indicates that very few mortality rates were as low as one third, and many were as high as 60 per cent or more. For example, studies of 7,655 householders in Provence exhibit a mortality rate of 52 per cent, while 79 studies of customary tenantry on manors across England show an average mortality rate of about 55 per cent. If we take into account the very high death rate among the poor, women and children, a general mortality rate of over 60 per cent is indicated.

### **What would the disease have been like for those who contracted it?**

**CR:** Even allowing for the exaggeration often found in medieval chronicles, first-hand descriptions of the Black Death make for grim reading. One account by a Franciscan friar from the Isles of Scilly describes the initial appearance of small pustules or buboes,

accompanied by a feeling of cold and stiffness, which would “so weaken and torment” the victim that he or she could no longer remain standing. Chill then gave way to a burning fever and searing pain as the buboes grew in size and the lungs became infected. By this stage, the victim would be coughing up blood and vomiting incessantly until death intervened approximately four days after the first signs of infection.

### **How were the afflicted treated by their families and communities?**

**MO:** Responses were many and various, with panic, flight and the mass burial of abandoned corpses all common. One consequence was the growth of religious guilds, which aimed to provide some level of security for people worried they would have no kin to attend to them in illness or remember them after death.

**Tom James:** Some were abandoned. In Winchester in 1349, for example, townspeople attacked a monk conducting a burial service. The townspeople also took over parts of the burial ground around the cathedral priory so that plague burials could not take place there.

designated for use in time of plague. A special Mass of St Sebastian was used, for example – Sebastian being one of the patron saints of plague, the arrow wounds of his martyrdom being a trope for the buboes of the plague which broke out on victims' bodies.

**MO:** The first outbreak of plague must have been an incredibly terrifying moment in human history. But medieval society was much more inured to natural and human disasters than is the case in the west today, and there is every sign that people re-established their lives remarkably quickly.

It was generally assumed that the plague was a result of poor air quality arising from high humidity or poor sanitary conditions. Although it took a long time to understand that the key cause of infection was the presence of rats, the idea of moving into the cleaner environment of the countryside did, in effect, provide some protection against infection for those lucky enough to escape the overcrowded towns.

**CR:** In England, the crown, parliament and local authorities did their best to contain such dangerous behaviour as the pollution of water supplies. Advice literature, increasingly produced in the vernacular rather than Latin, helped individuals and communities to avoid unnecessary risks. Spiritual health remained paramount, however, and although people may have grown less fatalistic in the face of disease they still regarded prayer and penance as their first line of defence.

### How did the epidemic change medieval society?

**MO:** If we take the long view, we can say that for at least a proportion of the survivors of plague, there was a real improvement in the quality of life. By the 15th century we find that people who survived to maturity tended to live longer than earlier generations because they were better fed, clothed and housed.

The drop in the population resulted in a redistribution of wealth: workers could demand higher wages, and tenant farmers could demand lower rents. This gave the poor more expendable income.

**CR:** Such a dramatic and sustained fall in population levels brought distinct benefits for ordinary people. On the whole, English men and women ate more meat and dairy produce than before and, in a rental market that favoured tenants rather than landlords, they were able to afford better quality housing.



## "In Rochester weeping parents brought their children to open pits and laid their bodies there"

Tom James

ABOVE: These lead crosses, found during the excavation of a London cemetery, may have lain with victims of the Black Death

The sanitary reforms introduced by urban authorities also made towns and cities cleaner and more pleasant places to live – or at least aimed to do so.

### What was the Black Death's impact on European history?

**OJB:** The historical impact of the Black Death and subsequent plague epidemics resulted in a temporary halt in the development of the early Renaissance, which was not resumed until about 1450. It oriented the mental focus and energy of the time towards death and salvation – *ars moriendi*, the way of achieving a good death, became of paramount importance. This found expression in the movement towards the Reformation, which broke down the authority of the Catholic church as a guarantor of salvation, and conferred to the individual the decisive task of achieving salvation through a pious and righteous life.

**TJ:** There's no doubt the Black Death was devastating when it first struck Europe between 1347 and the early 1350s. However the impact of the plague was exacerbated

because it returned in 1361, 1374, 1389 and then in 1665 with the Great Plague of London and elsewhere. At Eyam in Derbyshire, for example, it is reckoned that 260 out of a population of 350 died when they cut themselves off from the outside world.

Plague continued in France until around 1720 – prompting Daniel Defoe's fake *Journal of the Plague Year* (1722). In that sense, the grim reaper of the plague stalked Europe for centuries, breaking out like earthquakes, unheralded and randomly.

**MO:** The Black Death had a very different impact on western and eastern Europe – largely due to the response of the respective elites. In the west, the scarcity of population and the resulting increase in the economic capacity of the peasants meant that feudal lords were unable to enforce their traditional rights and had to engage in an open labour market. As a result, serfdom – the idea that peasant families were tied to the manor and had to perform unpaid service to their lord – simply became irrelevant.

In eastern Europe, conversely, the elites responded by reinforcing serfdom. The divergence was to be evident for centuries to come and had huge consequences for the levels of commercialisation and industrialisation experienced across Europe between the 16th and the 19th centuries.

### What do you think about recent research suggesting that gerbils, not rats, spread the disease?

**OJB:** The theory that the Black Death and subsequent plague epidemics arose among gerbils in east Asia according to climatic cycles should not be taken seriously. It is based on a series of erroneous or false historical assertions, like many other plague theories, such as that it was carried by human fleas and/or lice, or that it was, in fact, a viral disease that spread much like influenza.

**MO:** The gerbil theory is a fascinating idea but at the moment it is just a hypothesis. It's worth noting that the scientists involved are assuming the Black Death was indeed bubonic plague borne by fleas living on the backs of rodents: the only difference here is that the rodents may have been gerbils rather than rats.

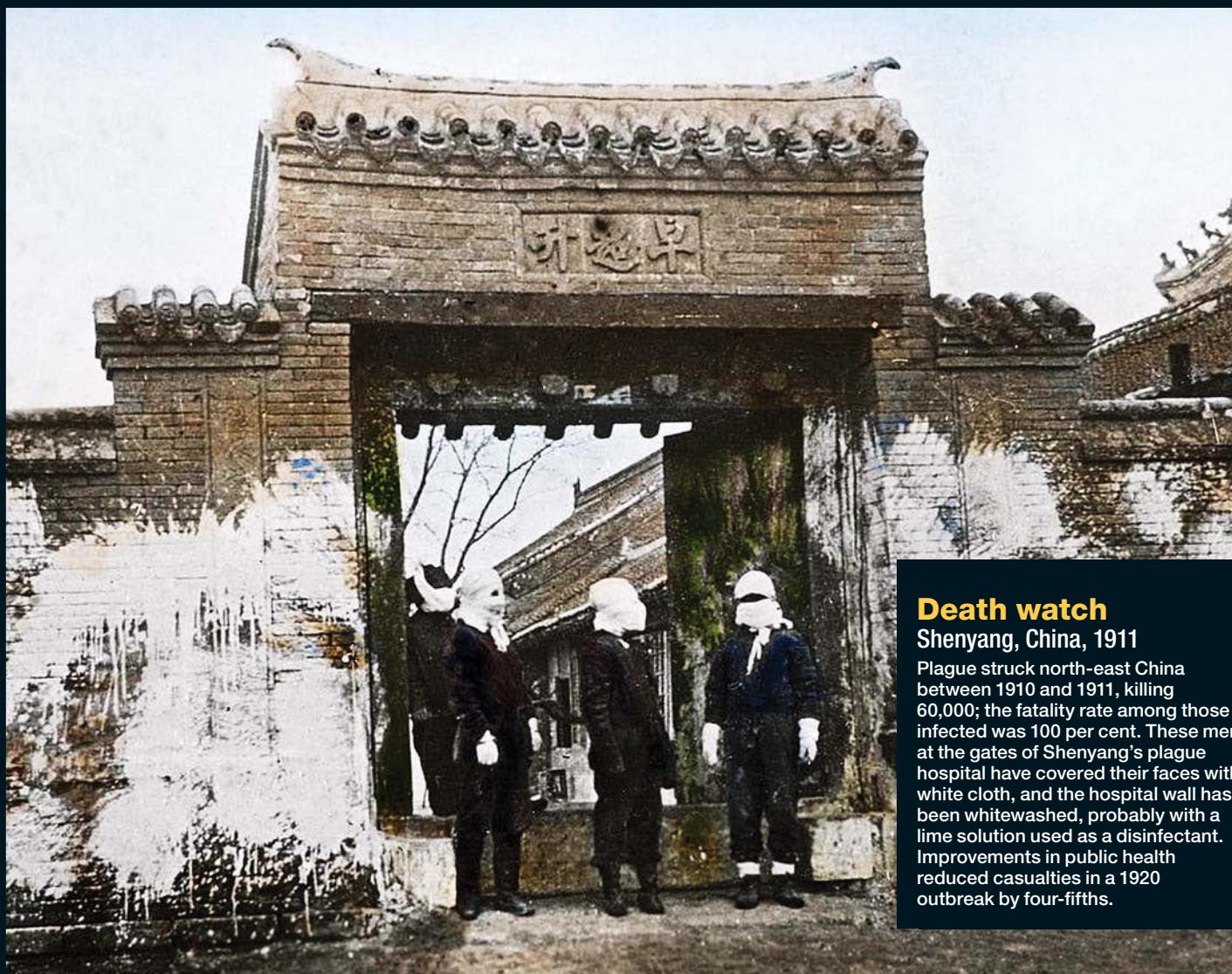
Other researchers in the past have suggested that the disease could have been anything from influenza to anthrax. All of this is a reminder of the many uncertainties that remain around the nature and spread of the Black Death pandemic. ■

RARE IMAGES

# PORTRAITS OF THE PLAGUE

Words by Charlotte Hodgman

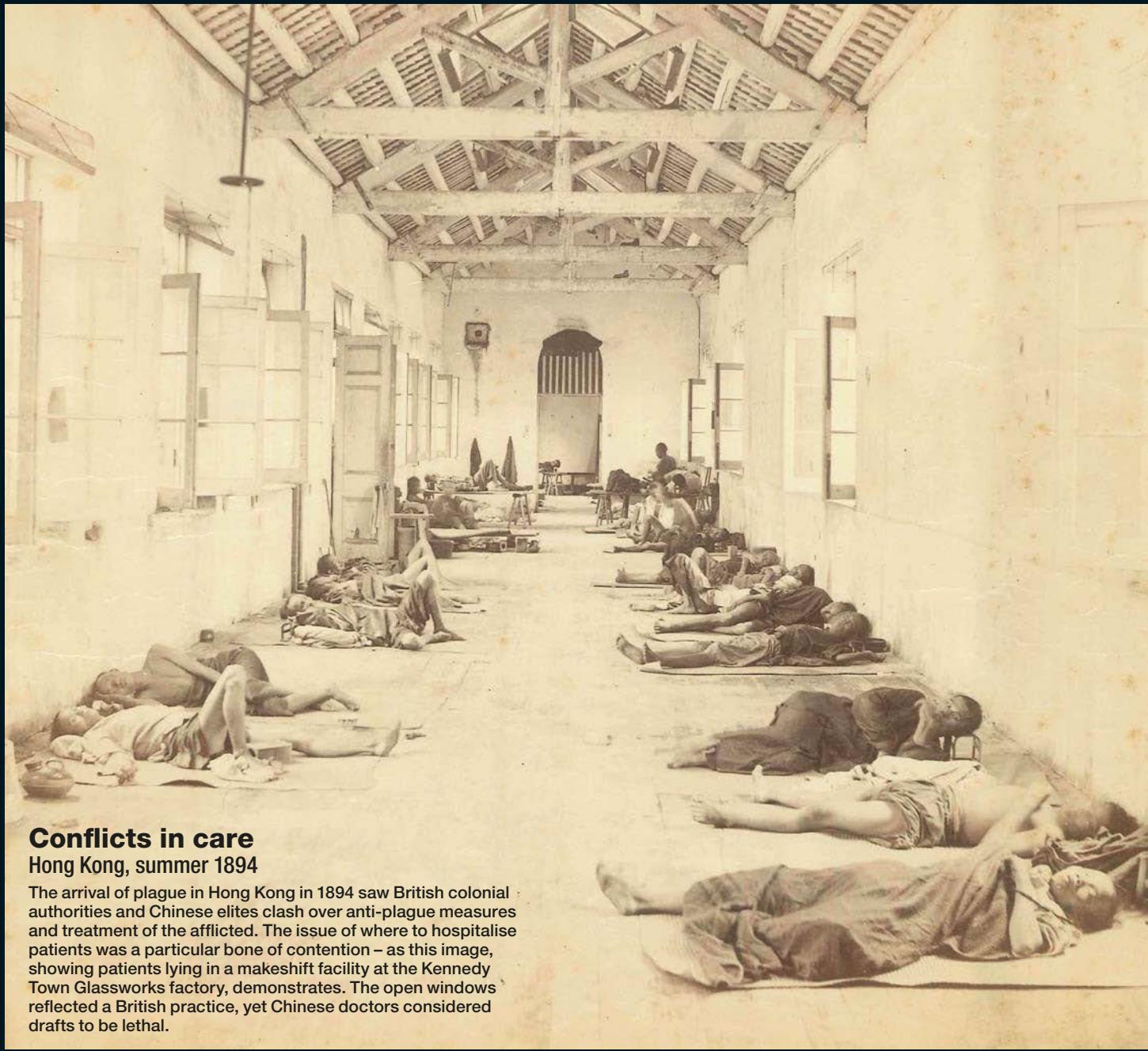
Between 1855 and 1959 – more than 500 years after the medieval Black Death – a new plague pandemic ravaged the globe, killing some 12 million people. Images collected in a new project vividly depict the outbreaks



## Death watch

Shenyang, China, 1911

Plague struck north-east China between 1910 and 1911, killing 60,000; the fatality rate among those infected was 100 per cent. These men at the gates of Shenyang's plague hospital have covered their faces with white cloth, and the hospital wall has been whitewashed, probably with a lime solution used as a disinfectant. Improvements in public health reduced casualties in a 1920 outbreak by four-fifths.



## Conflicts in care

Hong Kong, summer 1894

The arrival of plague in Hong Kong in 1894 saw British colonial authorities and Chinese elites clash over anti-plague measures and treatment of the afflicted. The issue of where to hospitalise patients was a particular bone of contention – as this image, showing patients lying in a makeshift facility at the Kennedy Town Glassworks factory, demonstrates. The open windows reflected a British practice, yet Chinese doctors considered drafts to be lethal.

## The Third Plague Pandemic

The Third Plague Pandemic (1855–1959) was unprecedented for a number of reasons. For the first time in history, bubonic plague reached all five continents, striking major cities from Hong Kong (in 1894) to Bombay (1896), Sydney (1900), Cape Town (1901) and Los Angeles (1924). The pandemic left an estimated 12 million dead (including 10 million on the Indian subcontinent), and saw the implementation of extraordinary measures for its containment.

The previous two plague pandemics (in

541–42 and 1346–53) had left society baffled as to its origins. Yet by the late 19th century scientists had a far greater understanding of plague – in fact, in Hong Kong in 1894, they were able to isolate the bacillus that caused it. By 1905, scientists had also acknowledged the role of the rat and the flea in plague transmission. Yet these discoveries did little to improve public health measures.

Quarantine, forced evacuations and torching neighbourhoods, such as Honolulu's Chinatown (1900), were all employed against

the pandemic, causing distress and conflict across afflicted areas.

As the first epidemic of any infectious disease to be photographed as it travelled across the globe, the pandemic left an extraordinary legacy of visual material. These images reveal the enormous, and diverse, impact of the plague on communities – from attempted regulation through de-roofing of houses and forced segregation, to efforts to control the way in which people dealt with the dead.



### Fire fight

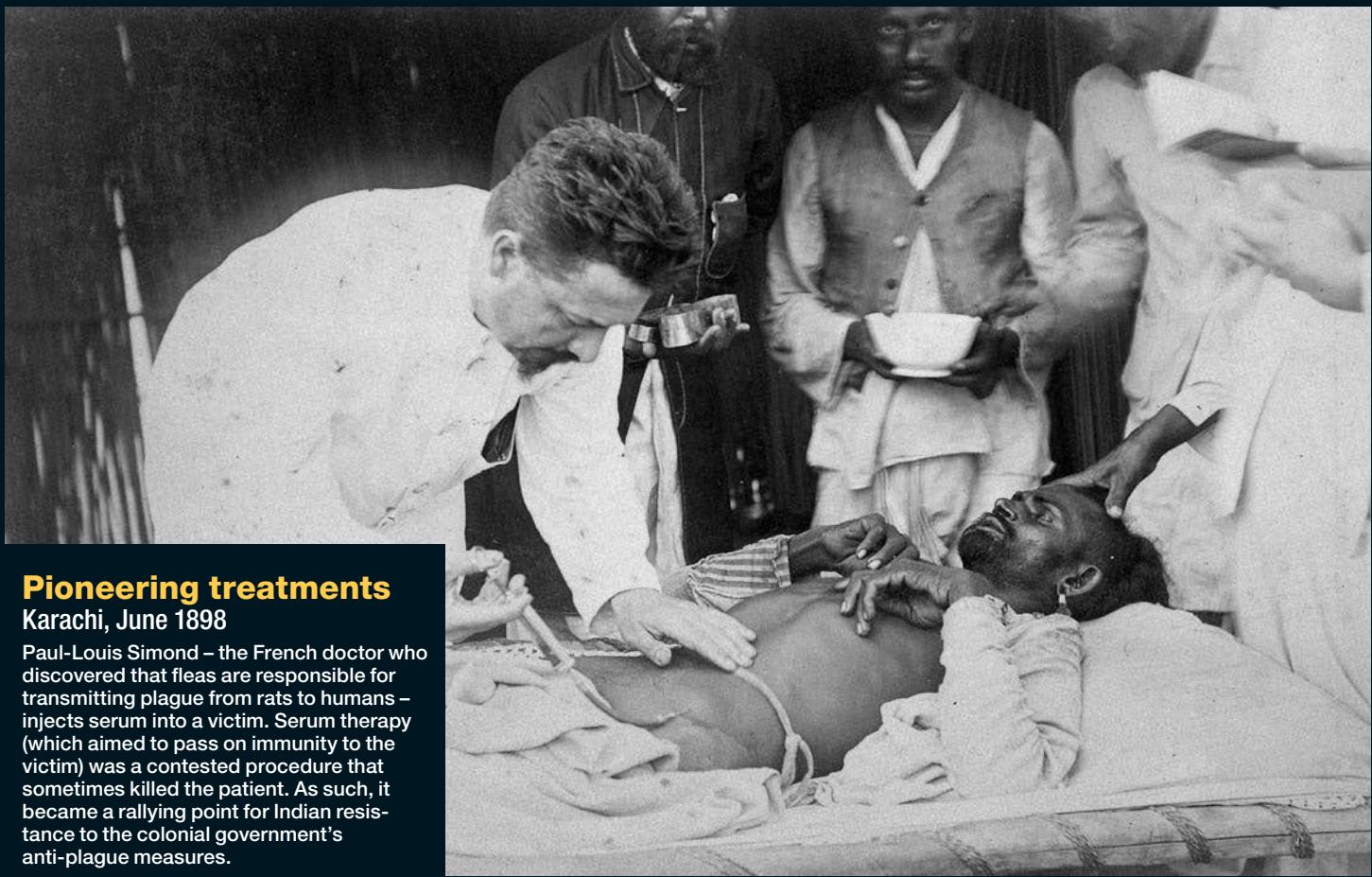
Honolulu, 1899–1900

Plague arrived in Honolulu in December 1899. In response, the authorities closed down the harbour and Chinatown. They also burned houses in Chinatown that were deemed to be insanitary, as shown here. On 20 January 1900, the burning of plague-infected buildings in this area of the city got out of control and an area of up to 65 acres went up in flames.

### Last rites

Bombay (now Mumbai), 1897

Hindu and Muslim funerary rites in India captivated the imaginations of colonial photographers. Images such as this, of a Hindu burning ground at Sonapur, littered the pages of the British press, relaying back news of the disease to a Victorian audience fascinated by what was, to them, the exotic social world in which plague was thriving.



### Pioneering treatments

Karachi, June 1898

Paul-Louis Simond – the French doctor who discovered that fleas are responsible for transmitting plague from rats to humans – injects serum into a victim. Serum therapy (which aimed to pass on immunity to the victim) was a contested procedure that sometimes killed the patient. As such, it became a rallying point for Indian resistance to the colonial government's anti-plague measures.

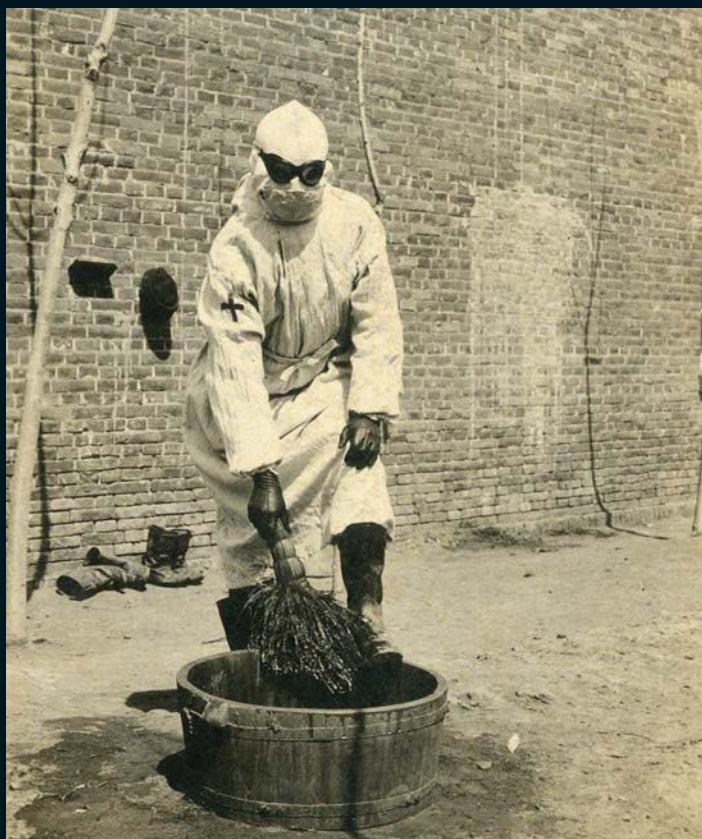


## Doused in petrol

Liverpool, c1900–20

In a bid to prevent the spread of the disease, men of the Liverpool Port Sanitary Authority dip rats into buckets of petrol to kill the fleas.

Though there was no widespread outbreak of plague in Britain, deaths were recorded in Cardiff, Glasgow and Suffolk. Cases were also reported in Liverpool, most notably in 1901, 1908, 1914 and 1916.



## Brush with death

Harbin, China, 1921

Protective measures were crucial in restricting the spread of plague. Here, a man in overalls, full face mask, goggles and gloves washes his boots during the 1920–21 epidemic in Harbin that caused 3,000 deaths. ■

### DISCOVER MORE

#### ONLINE

► The images in this feature were collated by the ERC-funded project Visual Representations of the Third Plague Pandemic, at CRASSH, University of Cambridge, led by Dr Christos Lynteris. For more details on their work, follow them @visualplague or go to [crassh.cam.ac.uk/programmes/visual-representations-of-the-third-plague-pandemic](http://crassh.cam.ac.uk/programmes/visual-representations-of-the-third-plague-pandemic)

# THE FUTURE OF GADGETS

# TECHHUB

EDITED BY DANIEL BENNETT

## ON THE HORIZON

### TESLA POWERWALL

The battery that could transform our energy use



**B**atteries are awful. For a start, they're always running out.

I can't remember the last time my phone didn't need a charge at the end of the day. That's not to say batteries haven't improved over the years. They have. The trouble is they've only evolved just enough to cope with our increasingly energy-hungry gadgets.

Clearly, the small inconvenience of having to charge my phone every night isn't the biggest problem the world is facing right now. But there is a conundrum on the horizon, and batteries will need to take a massive leap in order to solve it.

More and more homes and businesses are starting to wean themselves off fossil fuels, either through green energy suppliers or by installing solar panels on their roofs or windmills in their gardens. Thanks in part to a subsidy from the government, there were 650,000 residential and commercial solar installations in the UK at the end of 2014, powering the equivalent of 1.5 million houses. That figure is expected to grow again this year. The trouble with renewable energy is





Tesla Powerwall and a Tesla car compete in the 'Who's Shiniest' competition

PHOTO: AMAZON, GETTY, MARC HALL/NC STATE UNIVERSITY

→ its reliability. For example, solar power is only good until dusk, while wind power relies on the weather. This is where Elon Musk, the creator of PayPal, SpaceX and Tesla wants his new battery to step in.

The device, called the Tesla Powerwall, would be mounted in your home. It would soak up all the excess power generated by your solar panels, waiting to feed it back into the home during the night. Musk says his battery could store enough energy to power your home for an entire day. Indeed, the entire launch event was powered just by his batteries.

It's not just technology for the green-fingered either. The unit can be installed into any home and programmed to recharge during your energy providers' off-peak hours, stuffing itself with low-cost electricity before regurgitating it back into the house during peak hours, slashing your bills over the long-term.

At first, running your entire home off batteries might seem complete illogical.

But Musk is probably the only person in the whole world who could pull this feat off. For a start, his battery-powered Tesla Model S has three times the range of most other electric cars. Musk is using the knowhow gained in developing the best electric car in the world to try and build the best battery in the world. Right now, his company is busily building the biggest battery factory on the planet, named Gigafactory 1. Forecasts suggest that the factory will reduce Tesla battery costs by about 30 per cent.

The Tesla Powerwall will only be available in the US for now and costs \$3,000 dollars for a 7kW battery and \$3,500 for a larger 10kW system. Incredibly, the batteries are already sold out in the US until 2016. If Musk's plans are successful, he won't just be worrying the motoring industry, he'll have the energy companies panicking too. ■

**DANIEL BENNETT** is the reviews editor at *BBC Focus Magazine*

## TECHOMETER

### WHAT'S HOT

#### DRONE DELIVERY

When Amazon announced deliveries by drone, most thought it was just a stunt. But now, the company has submitted a patent for a system where a drone tracks the location of the person to whom it's delivering using data from their smartphone. The drones would also be able to talk to one another.



### WHAT'S NOT

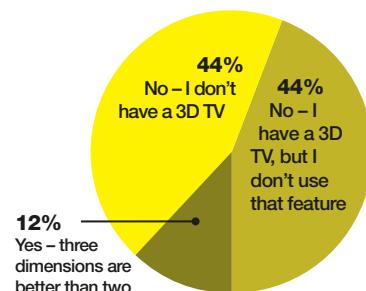
#### 3D TV

After five years, Sky is scrapping its 3D channel. Despite investing in original programming, including several David Attenborough documentaries, the channel failed to gain any real traction with viewers. It seems now that there are fewer and fewer options for getting 3D content, but keen viewers will still be able to access the channel through Sky's on-demand service.



### READER POLL

Do you watch any 3D content?



# THE NEXT BIG THING

## THE NANOCOMPUTERS ARE COMING

It has been 50 years since Intel's Gordon Moore noticed that the power of computer chips was doubling about every year. He coined this phenomenon 'Moore's Law'. Since then, we've seen enormous changes in the way the world works and in the types of technology that underpin our daily lives.

The assumption that we can rely on more computing power at less cost – and with reduced energy consumption – underpins many anticipated changes in the world, such as smart cities, self-driving cars and wearable computers.

Yet we can't rely on existing materials to deliver the sort of performance we will need, so we need to look elsewhere. The most promising developments are coming from nanotechnology – the design, manufacture and use of materials at the scale of 1-100 nanometres (one nanometre is a billionth of a metre) to build smart fabrics, intelligent roads and new forms of computer.

Nanoparticles are already out there, in things like sunscreen and scratch-resistant coatings

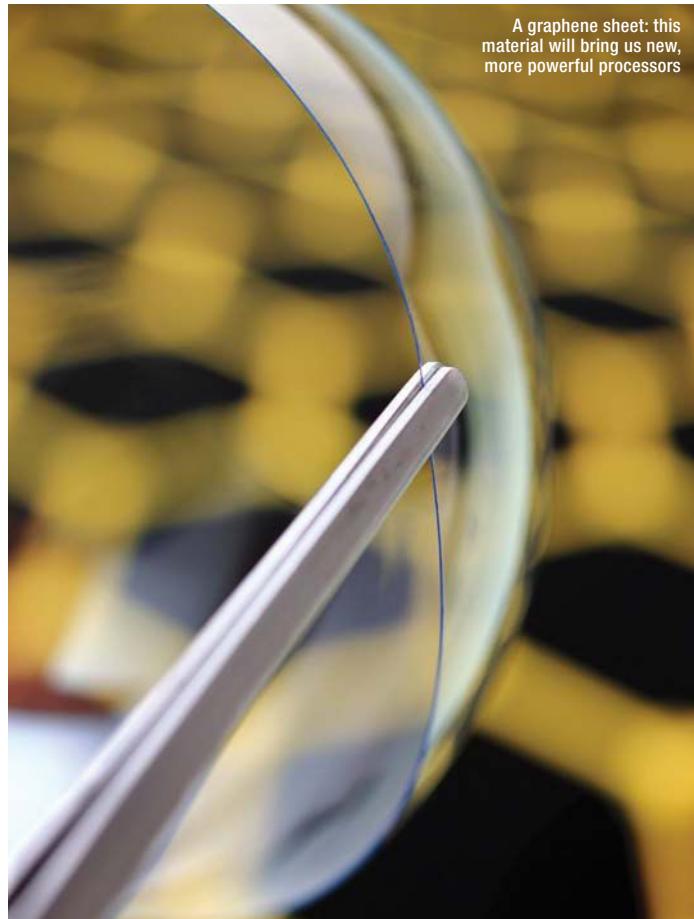
for glasses. For me, the exciting materials are those that can be used in computers, like graphene.

Graphene is a recently-discovered form of carbon. It looks like it can support a new generation of powerful processors that run cool and fast, letting us extend the lifetime of Moore's law by moving away from silicon-based computing.

And as that happens we can expect new possibilities to emerge, just as the move from valves to transistors transformed the sorts of electronic devices we could imagine. For example, we might have smart fabrics with sensors built in, keeping track of pulse, temperature and perspiration, and they'll also be responsive to the environment or your activity.

But the real impact will come when we know how to build these new types of device at scale, and to deploy them in ways we can depend on. I once asked Maurice Wilkes, who in 1949 led the team that built EDSAC, one of the world's earliest computers, what most surprised him about modern processors.

He said it was their reliability.



A graphene sheet: this material will bring us new, more powerful processors

EDSAC used 3,000 valves that were prone to burning out, so the machine would have to be repaired every few hours. In contrast, today's processors run trillions of instructions without error. For example, the laptop I'm currently using hasn't been rebooted for 15 days.

Before long it looks like we'll come to depend on these strange nanomaterials for computing. Their impact may not always be

positive, and it will definitely not be easily predictable. There are already concerns over the impact of some nanomaterials on the environment and on our bodies. But the new nanomaterials are coming, whether we prepare or not. ■



**BILL THOMPSON**  
contributes to  
[news.bbc.co.uk](http://news.bbc.co.uk) and  
the BBC World Service

### FROM THE LAB

#### The boots that put a spring in your step...

##### WHAT IS IT?

These boots are more like an exoskeleton than shoes and have been developed at the University of North Carolina. They strap around your shins and calves, mimicking the muscles and tendons. They make walking 7 per cent easier – equivalent to taking 4.5kg off your back.

##### HOW DO THEY WORK?

The boots are unpowered, instead relying on simple mechanics. Inside, there's a ratchet

that catches the spring and keeps it taut when your foot is flat on the ground. With the spring fully extended it holds elastic energy. When the walker lifts their foot the ratchet releases the spring and its stored energy, literally putting a spring in every step.

##### WHEN CAN I GET ONE?

The boots' engineers are working on a prototype that could help those with injuries or the elderly. According to one of the authors, we might see the boots "someday soon".



The exoskeleton helps people walk more efficiently

 **ULTIMATE TEST**

# TRAVEL

Whether you're jetting away or planning a staycation, here's our pick of the top tech that can make your life better this summer...



# TRANSFORMERS

## PANASONIC LUMIX DMC GF7 ▶

These days, taking a good selfie is as much a part of going on holiday as getting sunburn, fighting over sunloungers and getting sand in your shoes. To help you capture the perfect selfie, this camera's display flips 180°. In this mode, the device's AI takes a photo three seconds after it sees you waving. Similarly, if it sees two or more faces smushed together it'll take a pic. And for its party trick, if you pair it with a smartphone and activate Jump Snap mode, it will use the phone's accelerometers to calculate when your jump will peak and take a picture at the perfect moment.

[panasonic.com](http://panasonic.com)



## ◀ OVERBOARD WATERPROOF CAMERA CASE

This bag won't just protect your camera from water, sand, dust and mud, it'll also let you take pictures underwater. The camera case can safely venture six metres below the waves and will float back up to the surface if you accidentally drop it in the briny.

[overboard.com](http://overboard.com)



## POLAROID ZIP INSTANT ▶

Spare your pictures the fate of living permanently on your smartphone with this minuscule printer. No bigger than a Nintendo DS, it'll connect to your phone or tablet via NFC and Bluetooth to print your photographs, smudge-free, on 2 x 3 inch (5.08 x 7.6cm) sticky-backed photo paper in under 60 seconds. [polaroid.com](http://polaroid.com)



## ◀ COBRA JUMPACK

Taking a road trip this summer? This mobile battery charger can give your phone and your car a second lease of life. Plug the USB into your phone and the 7500mAh charger will give it another day's worth of charge several times over. But if your car's battery gives out, you can use the cables included to give your vehicle a jump start.

[cobra.com](http://cobra.com)



## EYEFI CARD ▶

Don't get strangled by cables. The Eyefi memory card has a built-in Wi-Fi chip that will send your photos to your tablet, PC, Mac or smartphone when both are connected to a trusted Wi-Fi network. Best of all, it'll also send those pics to the cloud, if you have a subscription, so that all your photos are immediately backed up.

[en.eyefi.com](http://en.eyefi.com)



## BRAVEN BRV-PRO ▶

If you're taking a speaker with you on holiday or to a festival, you'll want one that can handle anything. Built out of aircraft-grade aluminium, the BRV-PRO will roll with the punches, survive a dunk in water, and all the dust, mud or sand you can throw at it.

[braven.com](http://braven.com)



## NETATMO JUNE ▼

Keep tabs on the Sun with one of the best-looking wearables going. The June combines local weather reports and data from its UV sensor to tell you what factor sun cream you should be wearing and how often you'll need to reapply it to avoid any lasting damage.

[netatmo.com](http://netatmo.com)



## STEELSERIES STRATUS ▼

Keep the kids occupied with this videogame remote for your iPad. It makes longer, more engrossing games like *FFX* or *Need For Speed* much more engrossing – meaning that your sanity is more likely to be intact by the time you reach your destination.

[steelseries.com](http://steelseries.com)



## LOTUS GRILL ▲

Here's a barbecue that's purpose-built for the British summer. It uses a battery-powered fan to stoke just a handful of charcoal, providing enough heat to cook your burgers in the park. Best of all, the fat from your food can't reach the coals, so there's no smoke – meaning you can take it under cover when the rain clouds inevitably roll in.

[cuckooland.com](http://cuckooland.com)



## SMART KEY ▲

Never lose your keys on holiday! Pop them on this key ring and hook it up to your mobile via Bluetooth. If the phone loses the connection, it will start to sing. If you miss the alert, your phone logs the last GPS location where it had a connection and shows you how to get there via Google Maps. [elgato.com](http://elgato.com)

## OLLOCLIP ▲

These interchangeable lenses for your smartphone will give you one more reason to just leave your camera at home. Each Olloclip kit comes with a selection of four different lenses that slide over your smartphone's camera: a fisheye, a wide-angle and two macro lenses. [olloclip.com](http://olloclip.com)



## PARROT ZIKS 2.0 ▲

Ziks are the most versatile, noise-cancelling headphones money can buy. As well as drowning out plane engines, Ziks will customise audio output for each track through its phone app. All the controls are on the right can, so you don't have to fumble around for your phone to change the track. [parrot.com](http://parrot.com)

AND FOR YOUR NEXT HOLIDAY...

# 5 GADGETS YOU'LL BE ABLE TO BUY NEXT YEAR

## BLUESMART ►

Meet the ultimate suitcase. Before you fly, its built-in digital scale will tell your smartphone how much your luggage weighs, and when you're packed and ready to go you can lock the suitcase from your smartphone. It also comes with a built-in battery charger should your phone run out of juice. As well as logging your trip, it'll ping you its GPS location if you move out of range of the bag. If it's been lost, Bluesmart will track it down and ask if you want your bag brought to you by an Uber hire car. It can't arrive soon enough.

[Bluesmart.com](http://Bluesmart.com)



## ◀ GOJI SMART LOCK

Never leave a spare set of keys under the plant pot again. This smart lock lets you open your door from anywhere in the world, as long as your smartphone or tablet has an internet connection. Alternatively, you can give your friends and family access to your house for a couple of weeks. And if someone visits, Goji will take a picture and send it to you.

[Gojiaccess.com](http://Gojiaccess.com)

## PETCHATZ ►

If you can't bear to be away from Fido or Snuggles, there will soon be a way to keep in touch. This videophone drops a treat when you call to lure your cat or dog to the camera. Once they're there you can have a good chat – or whatever it is you do with a cat on a videophone – and you can even instruct the device to dispense a soothing scent to reassure your furry friend.

[Petchatz.com](http://Petchatz.com)



## RE-TIMER ►

Jetlag is a killer, but now it might have met its match: the Re-timer. These specs shine a green UV-free light into your eyes that's proven to help rejig your circadian rhythms. The idea is that four days prior to your next long-haul flight, you could wear the Re-Timer to slowly shift your sleep patterns to match those of the country you're visiting.

[Re-timer.com](http://Re-timer.com)

## ◀ SAMSUNG GEAR VR

Cramped seats, terrible food and air-con that dries you to a husk – we've all sat on a long-haul flight counting the hours to touchdown. Well, this mobile virtual reality headset could transform your flight, letting you play games and watch movies from the comfort of your own virtual world, leaving reality (and the plane) far behind.

[Samsung.com](http://Samsung.com)



# Q&A

## YOUR QUESTIONS ANSWERED

BY OUR EXPERT PANEL



**SUSAN BLACKMORE**

Susan is a visiting psychology professor at the University of Plymouth. Her books include *The Meme Machine*



**DR ALASTAIR GUNN**

Alastair is a radio astronomer at the Jodrell Bank Centre for Astrophysics at the University of Manchester



**ROBERT MATTHEWS**

After studying physics at Oxford, Robert became a science writer. He's a visiting reader in science at Aston University



**GARETH MITCHELL**

Starting out as a broadcast engineer, Gareth now writes and presents *Digital Planet* on the BBC World Service



**LUIS VILLAZON**

Luis has a BSc in computing and an MSc in zoology from Oxford. His works include *How Cows Reach The Ground*

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## Where is the biggest shipyard in the world?

PHOTO: STEPHAN GLADIEU/FIGAROPHOTO/CAMERA PRESS

**A** That accolade goes to the Hyundai Heavy Industries shipbuilding facility in the South Korean city of Ulsan. Built in the 1970s, the yard covers an area of 7.2 square kilometres. Its 10 dry docks turn out on average 80

vessels per year, comprising about 16 per cent of the global shipbuilding market. The massive Ulsan yard is incredibly versatile too, producing oil tankers, military vessels, container ships and car ferries. **GM**

In Numbers

# 750

is thought to be the max. number of mature European sturgeon in the wild. In the worst case scenario, the figure may be as low as 20

Q

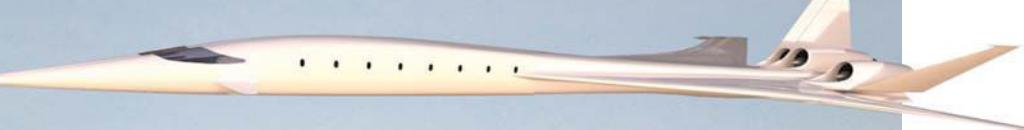
## Why aren't planets overcome by the Sun's gravitational pull?

**A** The planets don't crash into the Sun because they are moving too fast. Gravity pulls the planets towards the Sun, but the planets are also moving around the Sun. The sideways motion balances the force of attraction so that the planets don't move appreciably in the Sun's direction. In effect, the planets are constantly falling towards the Sun but always miss! Without the Sun's gravity to pull it 'down', the Earth would career off into space. Or, putting it another way, if the Earth stopped moving it would crash into the Sun. You can create a similar effect by swinging a large spring with a weight attached to one end. If you swing it fast enough, the spring won't stretch, unless it goes faster. But if it slows down, the spring will pull the weight in. **AG**



Q

## Will supersonic flights ever make a comeback?



**A** Within at least the next generation, the answer has to be 'very unlikely'. To understand why, one hardly needs to look further than the Airbus A380. The trend in aviation is to increase efficiency of aircraft, not speed. It's partly an equation of bigger planes, and thus less energy per passenger per kilometre. But the massive A380 also gains economies with its light carbon fibre frame, advanced avionics and engines with large air intakes that burn fuel more efficiently than smaller turbofans. Yet firms such as the UK's HyperMach believe they can

achieve hypersonic speeds at subsonic efficiencies by cruising at twice the altitude of conventional aircraft where the air is thinner. Hypersonic is faster than supersonic, and is generally defined as Mach 5 and above.

HyperMach plans to fly a prototype of its SonicStar plane in 2023. But even then, it will not quite be the beginning of fast air travel for the masses. The first planes would be executive jets, which would open up two-hour Atlantic crossings – but only to the mega rich. **GM**

Q

## Is there a way to walk across slippery surfaces without falling?

**A** Recent research at the Salk Institute for Biological Sciences in California found that we balance on slippery or narrow surfaces using clusters of RORa neurones in the spinal cord. These 'mini brains' process the huge amount of sensory information coming from your skin, muscles, inner ear and eyes and make hundreds of tiny corrections per second. It's a bit like the ABS in your car constantly watching for a skid and pumping the brakes before it happens. You can also reduce your chances of a fall by copying penguins. When you walk normally, your centre of gravity is only directly above the weight-bearing foot for a small part of each stride. If you waddle from side to side instead, your centre of gravity always stays above one foot or the other. This reduces the sideways forces and makes it much less likely that your foot will suddenly slip out from under you. **LV**



Walk like a penguin to avoid slippery mishaps



There's a serious glitch in The Matrix

## Q Can déjà vu be explained?

**A** The phenomenon of déjà vu is a sudden and intensely convincing feeling that you've been somewhere before, or that it has happened before. Many people jump to the conclusion that they dreamt the scene and now it's coming true. But there are no documented cases of people, in this state, predicting what's going to happen next. And many attempts to prove precognitive dreams have failed. An old theory is that déjà vu happens when one part of the brain senses something fractionally before another part,

wrongly setting off the feeling of familiarity. Another blames excessive or unusual temporal lobe activity. The temporal lobes handle many memory functions and are responsible for the sense of familiarity. Temporal lobe epileptics often report déjà vu. People with highly variable temporal lobe activity tend to be creative, believe in the paranormal and have lucid dreams, spiritual and out-of-body experiences as well as déjà vu. Next time you get this feeling, blame your temporal lobes. **SB**

Q

## Why does turning a device off and on often solve issues?

**A** Many devices run some kind of computer code. The software often runs in a loop, executing commands repeatedly while the device awaits input. For instance, your screen constantly refreshes until you press a button. Sometimes, the code slips into a non-functional permanent loop that only breaks when you reset everything by switching the device off and on. **GM**



Q

## Why do cats like boxes?

**A** Wolves, eagles, jackals, foxes and snakes prey on wild relatives of the cat. Cats hide in bushes or burrows during the day to escape their predators and to go to sleep. This behaviour lingers in domestic cats. A study at the University of Utrecht in the Netherlands found that cats in animal shelters were much less stressed by their new surroundings if they had a box to hide in. Even when cats aren't stressed, a box feels more secure, cosy and comforting. **LV**



If I fits, I sits

# TOP TEN MOST VITAMIN C-RICH FOODS



## 1. Guavas

Vitamin C in 100g: 228mg



## 2. Blackcurrants

Vitamin C in 100g: 200mg



## 3. Red peppers

Vitamin C in 100g: 190mg



## 4. Red chillis

Vitamin C in 100g: 144 mg



## 5. Parsley

Vitamin C in 100g: 120mg



## 6= Kiwis

Vitamin C in 100g: 93mg



## 7= Kale

Vitamin C in 100g: 93mg



## 8. Broccoli

Vitamin C in 100g: 89mg



## 9. Brussels sprouts

Vitamin C in 100g: 85mg



## 10. Strawberries

Vitamin C in 100g: 80mg



## Why does the Moon appear larger than normal on the horizon?

**A** It has been known since ancient times (at least as far back as Aristotle in the 4th Century BC) that the Moon can appear to be larger than normal when close to the horizon. At the same time, however, it can be shown that the Moon is in fact no different in size than when it is at the zenith. This dichotomy is known as the 'Moon illusion'. Ptolemy and others have tried to attribute the phenomenon to the

refraction due to the atmosphere, but this is in fact erroneous. Although there is no definitive explanation, it is generally accepted that it is merely an effect of perception. When the Moon is close to the horizon, other objects such as buildings and trees are included in the eye's field of view. Most authorities suggest that this makes the Moon appear larger than when it's surrounded by an expanse of empty sky. **AG**



Party time for werewolves

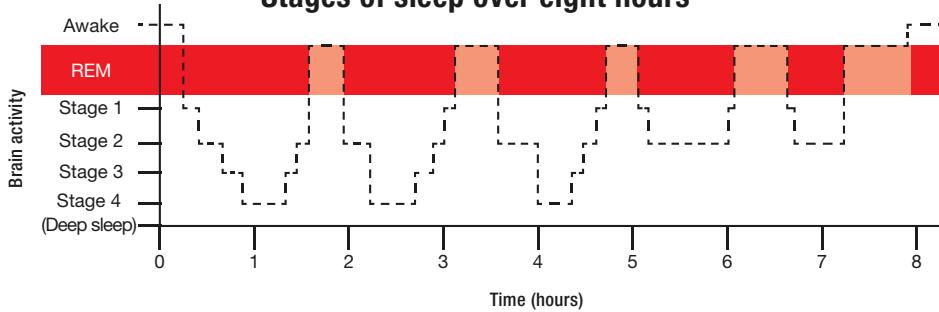


## Why do we toss and turn when we sleep?

**A** A typical night's sleep consists of REM and non-REM sleep. REM stands for Rapid Eye Movement and is named after the way your eyes dart around under your eyelids. REM sleep is when you dream. To prevent you acting out your dreams, nerve impulses from your motor cortex are intercepted in the spinal cord and blocked. So you'll never thrash about during a dream, no matter how vivid it is.

Instead, most of the tossing and turning actually happens in the brief moments after REM sleep when you wake up. This only lasts a few seconds and we usually don't remember having woken, so it feels like we are tossing and turning in our sleep. You can have four or five REM/non-REM cycles every night and the wakeful interludes give you a chance to change position or adjust the covers. **LV**

### Stages of sleep over eight hours





Q

**If I throw a ball up vertically in a moving train, will it move away from me?**

► No – it will land just as if you were standing still. That's because the ball started off in your hand, so was also travelling forward with the speed of the train. Once airborne, it doesn't lose that forward speed, so it keeps up with you and lands in your hand. **RM**



Play catch on the train

Q

## Why do people lie?

► To gain fame, riches, approval and attention; to refrain from hurting others or causing conflict; or to avoid admitting mistakes or seeming weak – there are many reasons. Liars prefer the consequences of lying to facing up to the truth, but the consequences of telling fibs are rarely benign. Relationships can be ruined by even small lies, exaggerating

can lower self-esteem, people who lie a lot become less trusting of others, and children are harmed by even little lies. It's hard to discover how often people lie, but one study of 2,000 British people found that men tell six lies a day, while women tell three. The most common lie was: "Nothing's wrong. I'm fine." **SB**

Q

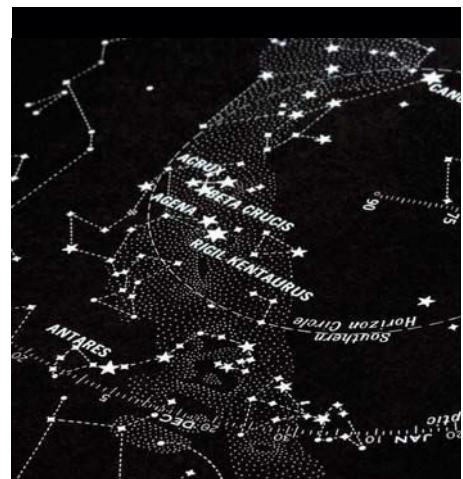
## What do dogs hear when we talk to them?

► There's good evidence that dogs can recognise many of the subtleties of human speech. A 2014 study at the University of Sussex found that dogs use the right side of their brain for processing the emotional content of speech, such as tone of voice, and the left side for verbal commands. Dogs can tell when a recognised command word is given, even when said with an unfamiliar accent. And they can tell the difference between correct commands, such as "Come on, then," compared to one with jumbled syllables, "Thumb on, Ken!" **LV**



Ate the Sunday roast?  
Me? Never!

PHOTO: ISTOCK X2, CORBIS, GETTY, FERMILAB, SCIENCE PHOTO LIBRARY



In reality, there are no scorpions and prancing goats in the sky

Q

## What are constellations?

► Constellations are merely patterns of stars that were originally associated with mythological or astrological figures. Many of them probably date back to the Sumerians. Usually, the only connection between the stars in a constellation is that they appear in the same part of the sky. They may, in fact, be located at very different distances. In modern astronomy, the constellations are defined not by the actual pattern of stars, but by a particular area of the sky with defined borders. **AG**

Q

## Does excessive screen time damage a child's brain?

**A** Serious screen addicts suffer sensory overload, lack of sleep, and loss of attentional control. Their brains show shrinkage of parts of the cortex, including the frontal lobes. These are important for planning, organising and controlling impulses. This is especially worrying in young people because the frontal lobes grow slowly and keep developing until their mid-20s. There are also changes in the brain's white matter, with long-range connections between neurones being interrupted. The arousal produced by exciting games affects the reward systems and alters levels of dopamine in the brain, which can have long-term effects on attention span. Relying so much on vision and movement may mean that other sensory areas are neglected, and children may lose out on building social skills and relationships. However, some screen-based activities develop new thinking skills, improve problem solving, enhance memory, and help hand-eye coordination, reaction speeds and multitasking. All of these can improve the growing brain. **SB**



### In Numbers

# 316,600

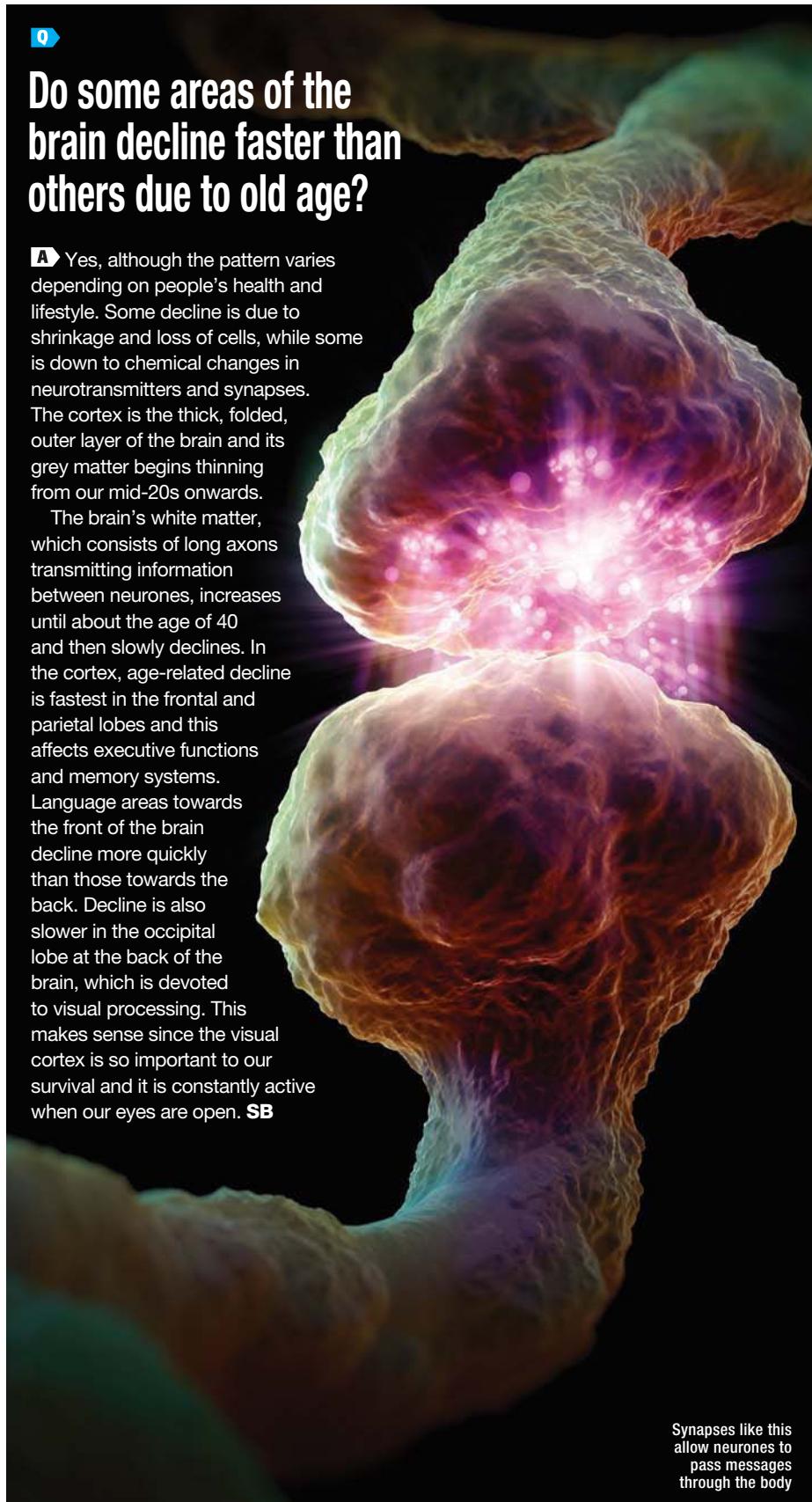
people over 100 years old live around the world. By 2050, this figure could increase to more than three million

Q

## Do some areas of the brain decline faster than others due to old age?

**A** Yes, although the pattern varies depending on people's health and lifestyle. Some decline is due to shrinkage and loss of cells, while some is down to chemical changes in neurotransmitters and synapses. The cortex is the thick, folded, outer layer of the brain and its grey matter begins thinning from our mid-20s onwards.

The brain's white matter, which consists of long axons transmitting information between neurones, increases until about the age of 40 and then slowly declines. In the cortex, age-related decline is fastest in the frontal and parietal lobes and this affects executive functions and memory systems. Language areas towards the front of the brain decline more quickly than those towards the back. Decline is also slower in the occipital lobe at the back of the brain, which is devoted to visual processing. This makes sense since the visual cortex is so important to our survival and it is constantly active when our eyes are open. **SB**



Synapses like this allow neurones to pass messages through the body

Q

## How much salt does it take to poison an adult?

**A** The medical literature lists an estimated lethal dose of between 0.75g and 3g per kilogramme of body weight. For a 75kg adult, that means a minimum of 56g of salt or about 10 teaspoons, taken all at once. But salt poisoning is about the concentration of

salt in your blood, not the amount that you eat. Your body will remove excess salt through your kidneys and your sweat. If you have access to plenty of fresh water, you can cope with a much higher salt dose than if you are dehydrated. **LV**



Q

## What makes a person's voice unique?



**A** Like a musical instrument, the sound of your voice is determined by the shape and size of its parts. The length of your vocal cords, the shape of your nose and the contours of your throat all contribute. The exact timing of the contractions of muscles in your mouth, tongue, larynx and diaphragm are different for everyone – even when they are saying the same words. These things are affected by the accents or cultures that surrounded us when we learned to speak. **LV**

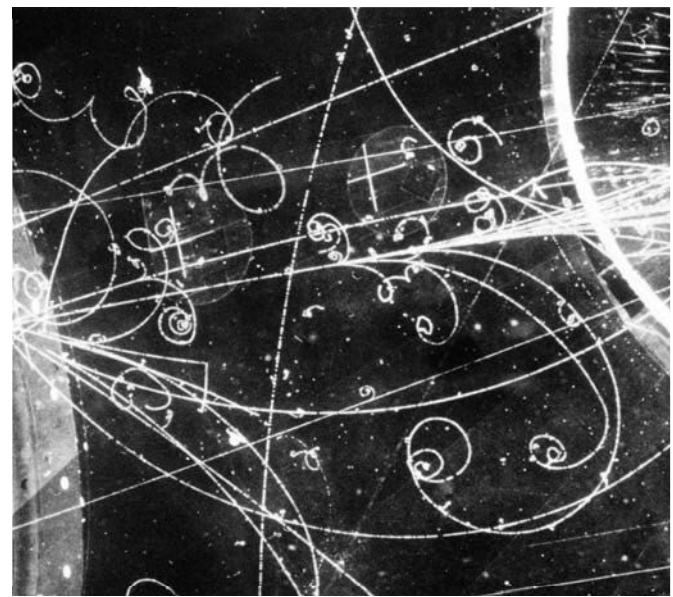
Q

## Have particles ever been detected travelling faster than the speed of light?

**A** According to Special Relativity, no particle with mass can travel at the speed of light – around 300,000 kilometres per second – let alone faster. But in 2011, a European team of scientists claimed to have found evidence of particles breaking Einstein's speed limit. Known as neutrinos, these particles were timed as they travelled over 700km from their origin at the CERN laboratory in Geneva to a detector in Italy, and they seemed to arrive around 60 billionths of a second sooner than a beam of light travelling through empty space could manage. Unable to explain the anomaly, the scientists asked for help. It quickly emerged that their

timing equipment was faulty, and the neutrinos had actually complied with Einstein's speed limit.

Physicist Robert Ehrlich of George Mason University in Virginia has argued that neutrinos may still be able to exploit a loophole in Einstein's theory, allowing them to travel faster than light. To do this, they have to possess so-called tachyonic mass, which is utterly unlike the conventional variety. According to Ehrlich, evidence that neutrinos are particles consisting of this stuff already exists in the results of lab experiments and in esoteric astronomical observations. Nonetheless, his interpretation remains controversial. **RM**



The paths of electrically-charged particles mapped in a bubble chamber



## Do some facial expressions cause more wrinkles than others?



**A** When you smile or frown, the creases in your skin begin as just temporary features. But as you get older, these same creases eventually become permanent wrinkles. Frowning mainly creases your brow, whereas a good smile will crease your eyes and mouth but not your

forehead so much. The only expression that creases the entire face is the kind of horrified wince you make when you watch someone take a bad fall off a skateboard (try it!). This suggests that watching a lot of YouTube videos might just give you wrinkles! **LV**

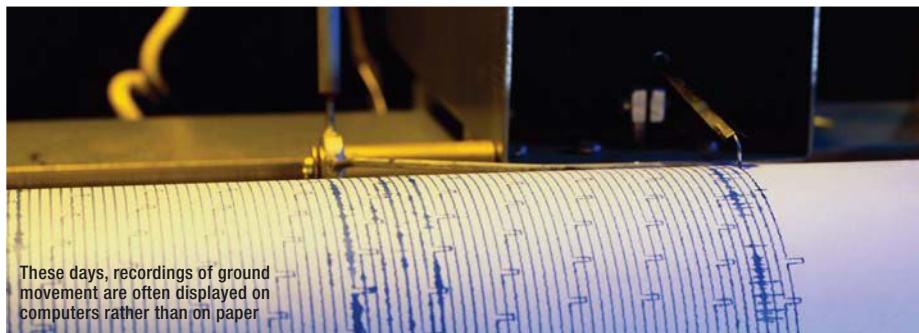


## Is it possible to accurately predict earthquakes?

**A** Scientists once believed they might one day find telltale signs of an impending earthquake sufficiently reliable to organise evacuations in plenty of time. Since the 1990s, however, the failure to identify any such useful 'precursors' has led to growing attention on two other strategies to minimise death and destruction.

The first strategy accepts that the time, location and size of an earthquake can never be predicted precisely, and focuses on identifying at-risk regions and making buildings and infrastructure

more quake-resistant. The second exploits the ultimate 'precursor': the vibrations caused by the earthquake itself. So-called P-waves spread out from the site of the earthquake at over 18,000km/h – giving about a minute's warning of the impending arrival of the much more destructive seismic waves. This is enough time for the authorities to switch off utilities and give the alarm so that people can find shelter. Both of these strategies are now in use in Japan and Mexico. **RM**



These days, recordings of ground movement are often displayed on computers rather than on paper



## Is it possible to take too many vitamins?



**A** Most definitely. The body normally regulates your levels of vitamins A, D and E, which you eat as part of a healthy diet. If you consume the vitamins in tablet form, you bypass this regulation mechanism and excess vitamins get stored in the liver, gradually building up over time. A daily dose of 2,500 micrograms of vitamin A for six months is enough to give you chronic vitamin A toxicity, with symptoms including blurred vision, hair loss and peeling skin. But you'd need to take more than 37 cod liver oil capsules a day to reach that quantity.

Taking vitamin supplements may even be bad for you – even at doses well below the toxic threshold. Probably the hardest one to overdo is vitamin C. The recommended daily intake for adults is 65 to 90mg (roughly one orange) but you can tolerate up to 2,000mg a day without any ill effects. At very high doses, vitamin C eventually causes diarrhoea, heartburn and kidney stones. **LV**

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## The Vital Question

Why Is Life The Way It Is?

Nick Lane

Profile Books 

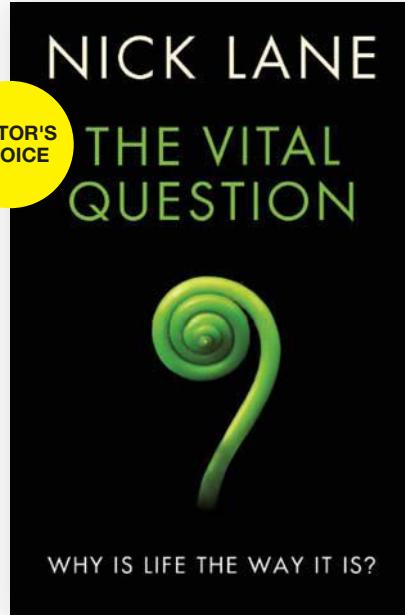
Every one of the millions of species on Earth uses DNA to make the genes that code for the proteins that constitute our cells and bodies. This tells us that all life – from single-celled bacteria to yeast, mushrooms, jellyfish, insects, plants, birds and mammals – can be traced back to a single common ancestor that, we now know from fossils, arose some time around 3.5 to 3.8 billion years ago.

But why does all life on Earth have only this one common ancestor? That's the 'vital question' at the heart of this book. Why have simple bacteria evolved into complex life just once in nearly four billion years? Why aren't there other forms of life with different basic chemistries? In Nick Lane's carefully researched new book, he argues that the answer lies in the way in which cells produce energy.

Lane identifies a particular chemical process – the proton pump – that is shared across all life. This process – a kind of electricity, except with protons flowing instead of electrons – is the principal source of a cell's energy. Lane suggests that if other, more efficient processes were possible, then natural selection should have allowed bacteria to discover them by now.

**“Why have simple bacteria evolved into complex life just once in nearly four billion years?”**

 EDITOR'S CHOICE



After all, bacteria are notoriously versatile, and they've had 3.8 billion years to come up with a better solution.

So how did bacteria make the leap to becoming complex life? Lane suggests that the breakthrough happened around 1.5 to 2 billion years ago, when a single bacterium took up residence inside another unicellular organism, creating the little energy powerhouses – mitochondria – that are found in most of our cells today. These mitochondria could then proliferate in cells, liberating orders of magnitude more energy than a bacterium could produce on its own.

It's no mere accident then, argues Lane, that we all stem from a common ancestor. Complex life requires colossal amounts of energy, and the chemistry that allows our cells to deliver it could not have happened in any other way. He even goes as far as to say that were we to find life elsewhere in the Universe, it would be fundamentally similar to our own.

This readable account of life's origins is unlikely to be the last word on this controversial subject, but it will intrigue the scientifically curious and challenge the biochemically literate.

.....

**MARK PAGEL** is a professor at Reading University and author of *Wired For Culture*

## MEET THE AUTHOR



**Nick  
Lane**

### How did life make the leap from simple bacteria to more complex forms?

In my book I argue that it was a bit of a freak accident about 1.5-2 billion years ago. A bacterium somehow got inside another single-celled organism, and this led to the development of mitochondria – the power packs of most of our cells today. This event removed the energy constraints that had kept bacteria simple.

### So it was a lucky accident?

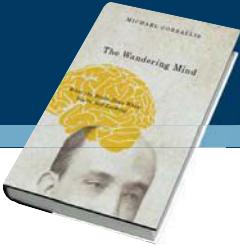
We know for a fact that complex life only evolved once [in four billion years]. It could be that [similar events] happened on multiple occasions but that existing complex life outcompeted any nascent life forms. However, we think that it was a genuinely rare event.

### Do we have evidence for this event?

If we look at our own genomes, we can see that a lot of our genes come from bacteria, and almost certainly from the bacteria that went on to become our mitochondria. We also see evidence from the mitochondria themselves, which have always retained their own bacterial DNA.

### How would you answer the question in the book's subtitle, after writing it?

I'd say life is the way it is because there are energetic constraints on evolution that have largely been overlooked. For the last 60 years we've thought about evolution in terms of DNA only – but that doesn't predict why life has the peculiar history that it does. If we bring the requirement for energy into evolution, we begin to see that life has taken its peculiar path for a fundamental reason. This should apply to life elsewhere in the Universe, too.



## The Wandering Mind

### What The Brain Doe

Michael Corballis

University of Chicago Press 

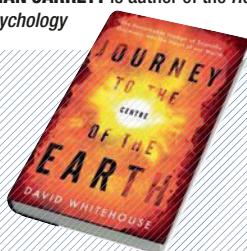
We spend at least half our lives off-task, our minds wandering into distant, imaginary worlds. We're taught from a young age that this is a bad habit, that we must pay more attention. But Corballis argues mind wandering isn't just important for creativity – it's an essential part of what makes humans unique.

Corballis uses the topic of the wandering mind to explore hallucinations, memory, dreams, creativity and more. Aptly enough, his prose style has an unfettered quality – a constant stream of facts, observations and asides. He is especially fascinating on the question of why we dream (perhaps it's to simulate real-life threats?) and on the drugs and other situations, such as sensory deprivation, that induce hallucinations.

Anyone who has studied psychology will find much that is familiar here, but there was certainly enough that was new to stop my own mind from drifting off. My favourite section is Corballis' demolition of the myth that 'right-brained people' are more creative. "We should relinquish our obsession with brain duality, and let the whole brain get on with it," he writes. Amen to that.



DR CHRISTIAN JARRETT is author of the *Rough Guide To Psychology*



## Journey To The Centre Of The Earth

### The Remarkable Voyage Of Scientific Discovery Into The Heart Of Our World

Dr David Whitehouse

Weidenfeld & Nicolson 



## Shrinks

### The Untold Story Of Psychiatry

Jeffrey Lieberman

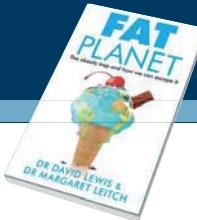
Weidenfeld & Nicolson 

In recent years, psychiatry has been under siege. In this book, former President of the American Psychiatric Association Jeffery Lieberman admits that psychiatry's past is strewn with dubious treatments like lobotomies, insulin coma and morphine therapies. But he argues that the discipline has cast off its unscientific past and matured "into a scientific medicine of the brain". ECT machines and psychiatric medicines effectively target discrete brain diseases; short-term therapies reprogram cognitive networks, while MRI scans record the real causes of mental distress.

The trouble is, this 'untold' story is one we have heard many times. Lieberman talks up the role of neuroscience in helping patients and oversells advances in treating mental disorders, while ignoring inconvenient truths such as the problem of over-prescription, the destructive effects of taking psychiatric medications long-term, or psychiatry's compromising financial ties to Big Pharma. His selective, one-sided account should be read more as a PR exercise than as a serious evidence-based contribution to the debate.



JAMES DAVIES is a reader in psychotherapy at the University of Roehampton, London



## Fat Planet

### The Obesity Trap And How We Can Escape It

Dr David Lewis and Dr Margaret Leitch

Random House 

*Fat Planet* is a review of the science of obesity and a look at the challenges people face when trying to lose weight. As the authors point out, the causes of obesity are complex; we need solutions that go beyond "eat less, move more".

We are born fat – human babies have nearly seven times as much fat beneath the skin as elephant seals – and get fatter. Why? Primarily, it seems, because we have big brains, and to fuel those brains we need large energy stores. The ability to lay down lots of fat was a great advantage to our ancestors, but for us it can have unfortunate consequences.

Genes and the wrong gut bacteria can contribute to the problem, but it is impulse control that the authors identify as one of the key things to focus on. They point to research which shows that by improving sleep and exercise habits and minimising stress, we can develop better self-control. But as they ruefully acknowledge, 'bolster your cognitive resources' is not a great slogan.

Broadly, their solutions are centred on ways to reduce temptation at either state or individual level – though I found some more convincing than others.



MICHAEL MOSLEY is a science writer, doctor and BBC science presenter

We know more about the cosmos above our heads than about what's beneath our feet. The closest we've come to Earth's core is when three men dived 10km to the bottom of the Mariana Trench. While volcanic lava holds mineralogical clues, and seismographs and neutrinos reveal strata secrets, great unknowns remain about what lies beneath. What is the mantle made of? How does the core generate Earth's magnetic field? How deep can life survive?

Author and broadcaster David Whitehouse delves into these questions using Jules Verne's *Journey To The Centre Of The Earth* as a background narrative. Serving up intriguing

information about the first seismoscope and so-called 'deep diamonds', he travels from the crust to the core, explaining everything from continental drift to the dynamo theory.

The book slightly lacks structure, and the chapter on 'underworld' theories through the ages doesn't sit easily with the rest. But overall, Whitehouse does a good job of explaining how our planet's internal organs mould its continents.



JHENI OSMAN is a science author whose books include *The World's Great Wonders*

# HOLLYWOOD SCIENCE

## Killer robots in Terminator Genisys

He said he's back and he only went and did it. Fresh from his work placement as Governor of California, this movie sees an ageing Arnold Schwarzenegger return to his rightful role as the Terminator in the franchise's fifth instalment. In Terminator Genisys, it's humans against machines. There are melt metal men, robots with guns, and accents so thick they make Cheryl Fernandez-Versini sound like Mary Poppins. You know the score. Yada yada yada.

In contrast to Arnie, killer robots of the future are unlikely to look like a pair of tights stuffed with walnuts. Instead, they'll come in the form of unmanned aerial vehicles. Driven by computer algorithms and armed with sophisticated tech, the drones would detect, select and kill targets without our involvement. It's a chilling thought. And if you think the technology is too far off to worry about,

## "Let's hope legislation gets here in time to avert Terminator 6: Geriatric Day"

think again. The Israelis already have autonomous radar-destroying drones, while the South Koreans use machine gun-wielding robots to defend their border with the North. 'Automatic target recognition', where computers determine the target but humans pull the trigger, is already under development. Next generation drones like BAE Systems' Taranis or Northrop Grumman's X-47B could find themselves hosting this tech. "We're already blurring the lines between human- and machine-controlled decisions about attack," says Thomas Nash, Director of Article 36, a UK-based organisation campaigning to ban devices of this nature.

But the final step, removing all human involvement, is a line that should never be crossed. "It would de-humanise violence, conflict

ILLUSTRATOR: ALEXANDER WELLS



and killing in a way that is morally repugnant," says Nash. "This is about human life and dignity. Machines will never understand that. We need legal protection in place that says this is something that humanity as a whole doesn't want." With this in mind, the United Nations recently held its second meeting on the subject, where representatives of the world's major military powers tried to thrash out what constitutes meaningful human control – the level of involvement that is needed to kill someone on the battlefield or in law enforcement. There are many instances where weapons such as landmines and cluster bombs have been banned at the international level, and discussions like this are a necessary first step towards international legislation. But with the best will in the world, any treaty or formal ban is at least a year or two away. Let's hope the legislation covers Hollywood and that it gets here in time to avert Terminator 6: Geriatric Day. ■

HELEN PILCHER is a science writer and comedian. She tweets from @Helenpilcher1

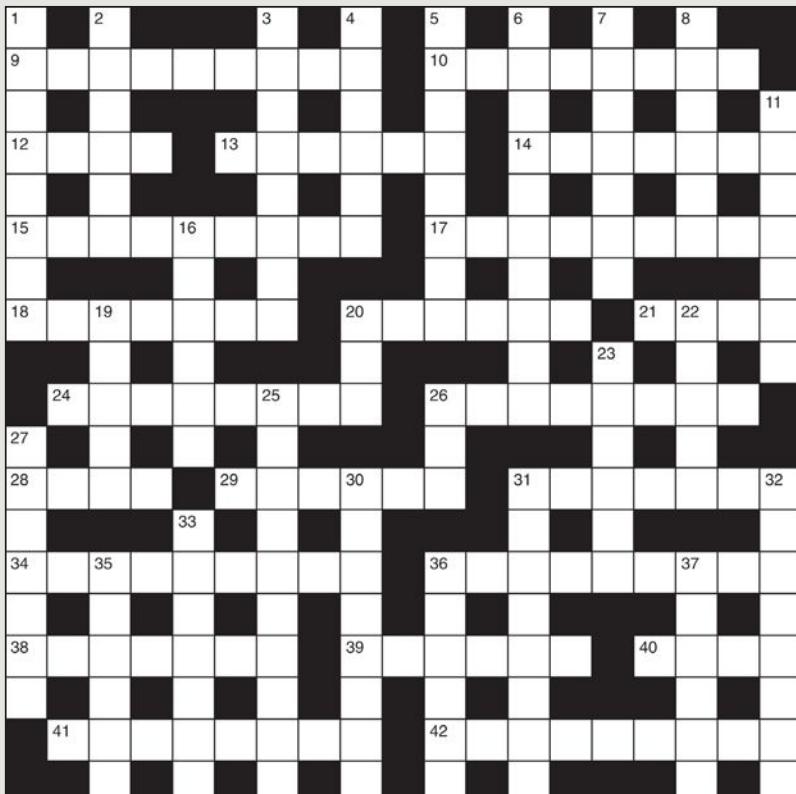
## Crossword No.179

### ACROSS

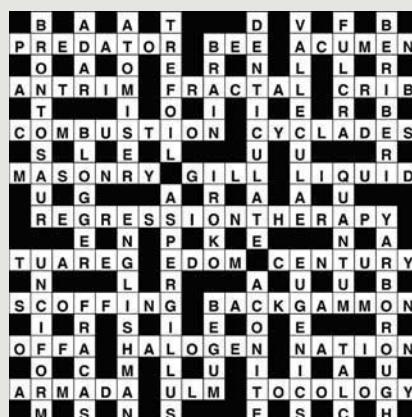
- 9 Health centre is initially round, sloping the same way (9)
- 10 Tempest not affecting Parliament buildings (8)
- 12 First man to encounter a barrier (4)
- 13 Hide display unit (6)
- 14 Article on beam gets pressure treatment (7)
- 15 Man United redesigned outer coverings (9)
- 17 Consider gold telescope (9)
- 18 Mother left song as a complaint (7)
- 20 Quiet and shy about one old form of exercise (6)
- 21 Growth of doctor on ship (4)
- 24 Longed to have a small drink, having flippers (8)
- 26 Mention about Roy breaking large mineral (8)
- 28 Hard-worker outside city of stone (4)
- 29 Fish, having no current at the surface (6)
- 31 Somewhat surrounded by fat cord (7)
- 34 Choose staff at eastern terminal (9)
- 36 Monotonous sound follows fire at plant (9)
- 38 Generous politician (7)
- 39 Wild dogs – alternatively, a pointer (6)
- 40 Hand over new hostage (4)
- 41 New coins, say, causing skin discolouration (8)
- 42 Folds in hepatic development (9)

### DOWN

- 1 One hesitation, following giant element (8)
- 2 Pool around the French territory (6)
- 3 A don can work with a snake (8)
- 4 Part of the eye clears differently (6)
- 5 No coordination when variable neutron turns grey (8)
- 6 Imaginary creature has time to wave hairy foot (5,5)
- 7 A couple of Frenchmen using tree gauge (7)
- 8 Child at home with fellow worker (6)
- 11 Conifer gives fancy ending to reporters (7)
- 16 River is in state of the sea (6)
- 19 They're not clerics and are upsetting Italy (5)
- 20 Cushion at home (3)
- 22 Only it's a terribly old port (5)
- 23 Surface temperature on Mars, say (6)
- 25 Expert to use lamps to see contents of cell (10)
- 26 Copper gives daughter second-hand food (3)
- 27 Heart all broken by cockatoo (7)
- 30 Honest – actors are mine (8)
- 31 Girl has rods fixing spinal curvature (8)
- 32 Deterioration of soldiers in a diet experiment (8)
- 33 Directions have entry about volatile liquid (7)
- 35 Worried more by early development (6)
- 36 Father right to fetch plaster (6)
- 37 Scripture lessons have a lot about bridge (6)



### SOLUTION TO CROSSWORD 176



# The Last Word

## Habitable planets may turn up in surprising places

**T**he study of planets orbiting distant stars is revolutionising our understanding of the Universe. This year is the 10th anniversary of the first discovery of a 'super-Earth', orbiting a star called Gliese 876. The planet's mass is larger than the Earth's, but smaller than that of Neptune or Uranus. Such worlds and the other 'exoplanets' present new opportunities to find life.

It used to be thought that a liveable world had to orbit in the 'habitable zone' (HZ) of a Sun-like star, at a distance that would allow liquid water to gather on the planet's surface. This seems plausible if you look at the Solar System. Venus is an inferno just inside the HZ. Mars, just outside, is frozen, while Earth seems just right.

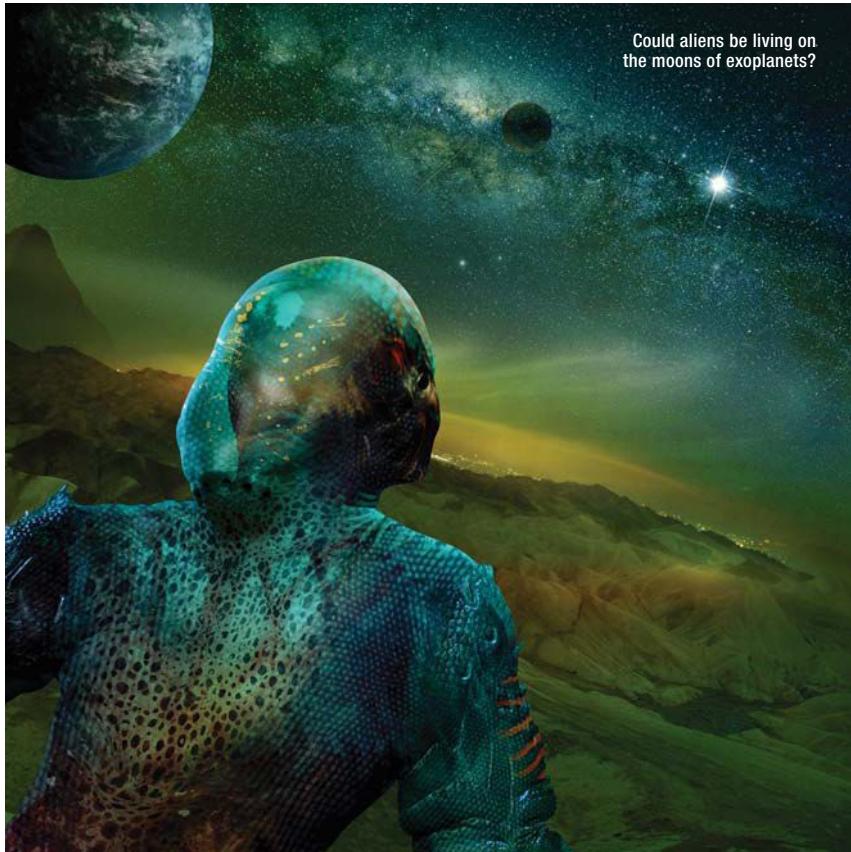
But a rule-breaker, whose plausibility has been recently confirmed by astrobiologist Rory Barnes of the University of Washington, was shown in the movie Avatar. Pandora is a moon of the gas giant Polyphemus, which orbits a star of the Alpha Centauri system just outside the traditional HZ. But Pandora is kept warm by complex effects that include tidal heating from its parent world.

Even in our own Solar System we have found liquid water far from the HZ. Jupiter's moon Europa has a crust of ice; beneath this lies an ocean, which is kept liquid by tidal effects. There may be as many as six of these 'ocean worlds' among the outer planets' moons. Future space probes will determine whether these dark and briny seas are capable of hosting life.

On the other hand, the exoplanets show us that having liquid water is no guarantee of habitability. The super-Earth GJ 1214b, 42 light-years from the Sun, may have an ocean thousands of kilometres deep. The ocean floor is comprised of an exotic kind of ice, which is made solid by high pressure rather than cold. It's not clear if life could evolve cut off from the minerals of the world's rocky core.

Meanwhile, we no longer even think the parent star has to be like our Sun. Red dwarf stars like Proxima Centauri (as featured in my novel *Proxima*) are small and dim. A habitable planet would have to huddle so close that it would be 'tidally locked', like the Moon is to Earth, with a single face perpetually presented to the star. But since 70 per cent of stars are red dwarfs, this model multiplies the potential number of habitable worlds in the Galaxy many times over.

The habitability of a given world can also change with time,



**"Since 70 per cent of stars are red dwarfs, this model multiplies the potential number of habitable worlds in the Galaxy"**

and can be affected by life itself. The film *Jurassic World*, out in June, shows us creatures from an age when Earth was warmer and more oxygen-rich – an ideal environment for huge land animals. More dramatically, Earth was once perfectly habitable for anaerobic (oxygen-hating) bacteria. The evolution of photosynthetic bacteria, which released oxygen into the atmosphere, changed all that. According to James Lovelock's 'Gaia' model, over the five billion years since its formation, the Sun has gradually increased its power output. Its HZ has therefore shifted across space, from well within Earth's orbit to its current position. And yet Earth's surface temperature has remained stable, thanks to the action of immense flows of mass and energy which act like natural thermostats. Life is intimately involved in these systems – in other words, life itself may maintain habitability.

So the definition of a 'habitable' world is more tricky than it first appears. But the Universe as a whole looks a lot more hospitable to life than it did mere decades ago. ■

**STEPHEN BAXTER** is a science fiction author who has written over 40 books. His latest is *Ultima*, published by Orion



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